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NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 561

SUBMARINE STEERING AND DIVING SYSTEMS

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CHAPTER 561

SUBMARINE STEERING AND DIVING SYSTEMS

SECTION 1.
INTRODUCTION

561-1.1 TYPES OF HYDRAULIC SYSTEMS

561-1.1.1 GENERAL. Submarine steering and diving control surfaces (rudder and diving planes) are positioned by means of mechanical linkage controlled by a hydraulic ram. The hydraulic systems used to operate the ram vary significantly among the different classes of submarines. Operational modes have been somewhat standardized, but the operating pressures, control types, and power sources have undergone considerable change and development. Submarine steering and diving hydraulic systems may be classified as variable or constant pressure systems.

561-1.1.2 VARIABLE PRESSURE SYSTEM (PRESSURE DEMAND). A variable pressure system is essentially a type of pump system that requires a separate pumping plant for each control surface. Because the load determines the operating pressure, this system is commonly referred to among submarine personnel as the pressure-demand system. The pressure developed by the pump is only that required by the load itself and any pressure loss in the system. Therefore, with this type of system, the operating pressure varies as a function of ship speed and control surface position. Both variable-volume and constant-volume pumps have been used for the independent power plants that must be used in a pressure-demand system. Although the use of reversible, variable-volume pumps has many advantages, the constant-volume screw pump is usually selected on the basis of its quieter operation.

561-1.1.3 CONSTANT-PRESSURE SYSTEM. In a constant-pressure system, an accumulator is usually employed to establish system pressure. The system pressure is directly determined by the air charge placed on the accumulator. The pump discharges to the system at this pressure regardless of the pressure required to move the load. Pressure in excess of that required to move the ram is dissipated by throttling the oil flow through directional and flow-control valves. An unloading valve is usually provided to bypass pump discharge to the tank at low pressure during periods when no ram movement is required. During these periods, the accumulator maintains the system at high pressure. With the constant-pressure type of hydraulic system, the power source may be either an independent power plant or one of the ship's hydraulic systems.

561-1.2 POWER SOURCES AND MODES OF OPERATION

561-1.2.1 All steering and diving systems have more than one power source so that in the event of a failure an alternative means of control is available. The power source for all operational modes is given by ship class in Table 561-1-1. To transfer from one power source to another generally requires transferring from one mode of operation to another mode. All submarines have at least three modes of operation, generally designated Normal, Emergency, and Hand (or Local). Most recently constructed ships also have an automatic control mode which is discussed in paragraphs 561-1.4 through 561-1.4.4.2. Operational characteristics are as follows.

561-1.2.2 The usual operating mode is normal mode. The mode of operation used when normal mode fails is emergency.

561-1.2.3 In the hand or local mode of operation, the hydraulic power source is usually a manually powered pump. On the fleet submarine, the hand mode of operation was used to provide silent operation as well as an alternative means of control in the event that both normal and emergency modes were inoperative. Starting with SS 580 Class, hand operation has been installed only as a means of positioning the control surfaces after the failure of both normal and emergency modes of operation. The hand pumps are installed near the rams rather than in the control room. Positioning of the control surfaces on these ships is slow (due to large capacity rams), and is normally used only to center (zero angle) the control surface. To control the ship with hand operation is most difficult even with a substantial reduction in ship speed. On the SSN 594, SSN 608, and SSBN 616 Classes, local dc-powered vane pumps are installed in lieu of hand pumps. These battery-powered pumps are capable of moving the control surfaces at 1/3 to 1/2 degree per second at forward ship speeds of approximately 6 knots.

561-1.2.4 In conjunction with local control, many submarines also have the capability to aline the hydraulic system in such a manner that the control surfaces can be powered by the main or vital hydraulic system through the local hydraulic control valve. Starting with the SSN 688 Class, the handpumps were deleted and local control consisted of a local hydraulic control valve, with the ship's service hydraulic system as the power source.

561-1.2.5 Along with the conventional emergency control mode, SSN 685, SSN 688 Class, and TRIDENT are provided with a stored-energy system for the stern diving planes. The system consists of accumulators dedicated to the task of powering the planes 1-1/2 cycles in the event of failure of both normal and emergency power sources. Stern plane movement, when using stored energy, is controlled by means of the emergency control valve.

561-1.3 TYPES OF MANUAL CONTROL

561-1.3.1 RATE CONTROL. In steering and diving systems that employ rate control, the direction of the control surface movement is determined by the direction in which the control wheel or stick is removed from the neutral position. The rate at which the control surface moves is determined by the amount the control wheel or stick is displaced from the neutral position. To stop control surface motion, the control wheel or stick must be returned to the neutral position. The control stick is normally spring-centered to the neutral position so that the operator need only release the control to stop the control surface movement.

561-1.3.2 POSITION CONTROL. With position control, the position to which the operator moves the control wheel or stick determines the angle ordered and transmits an input signal to a summing unit of a servo system. The actual position of the control surface determines a feedback signal that is also transmitted to the summing unit. In the summing unit the feedback signal is subtracted from the input signal. The difference is the error signal, which actuates the servo control valve for the system. When the control surface reaches the ordered position, the feedback signal equals the input signal. The error signal is then zero and movement of the control surface is stopped.

561-1.3.2.1 Prior to SSN 688 Class, position control and rate control generally were used for normal and emergency modes of operation, respectively. SSN 688 Class and TRIDENT Class use position control for both normal and emergency modes of operation. Normal control basically consists of an electro-hydraulic servo control system, whereas, emergency control is a mechanical-hydraulic equivalent of the normal mode system.

561-1.4 AUTOMATIC MODES OF CONTROL

561-1.4.1 GENERAL. Generally, all nuclear submarines have had an additional operating mode referred to as automatic. Many variations of this basic concept have been installed. In each, the hydraulic rams are controlled by means of the normal-mode hydraulic servo valve and the normal power source; however, the input to the servo valve does not originate at the control stick. Basic automatic control systems are discussed herein, but many of the initial installations have been removed and replaced as a result of obsolescence and high maintenance costs.

Table 561-1-1. HYDRAULIC POWER SOURCES FOR STEERING AND DIVING

Ship Class	Normal*	Emergency**	Hand or Local Control
SS 567	Independent Power Plants (Pressure Demand)	Main Hyd Sys	Handpump Operation of Main Hyd Sys
SS 574	Independent Pressure Demand System	Main Hyd Sys	Control-Station Handpump
SSN 575	Independent Pressure Demand Power Plants	Vital Hyd Sys (Except External Hyd Sys for Bow Diving)	Control-Station Handpump
SS 576, SSN 578 Class	Main Hyd Sys	Vital Hyd Sys	Control-Station
SS 580 Class	Main Hyd Sys	Vital Hyd Sys	Handpump Local Handpump
SSN 597			
SSN 585/588 Class SSN 598 Class	Main Hyd Sys	Vital Hyd Sys	Local Handpump Main Hyd Sys For Steering & Stern Diving
SSN 594 Class SSN 608 Class SSBN 616 Class	Main Hyd Sys	Vital Hyd Sys	Local D.C. Motor-Driven Pump
SSN 637/678 Class SSBN 640 Class SSN 671	Main Hyd Sys	Vital Hyd Sys	Local Control - Main Hyd Sys & Handpump
SSN 685	Main Hyd Sys	(1) Vital Hyd Sys (2) Stored Energy Accum. (Main Hyd Sys)	Local Control - Vital Hyd Sys & Handpump
SSN 688 Class Fairwater Diving	Stbd Hyd Sys	Port Hyd Sys	Stbd Hyd Sys
SSN 688 Class Steering	Combined Steering & Stern Diving Power Plant	Port Hyd Sys	Stbd Hyd Sys
SSN 688 Stern Diving		(1) Stbd Hyd Sys (2) Stored Energy Accum (Port Hyd Sys)	Port Hyd Sys
TRIDENT Fairwater Diving Steering Stern Diving	Stbd Hyd Sys Port Hyd Sys Independent Hyd Power Plant	Port Hyd Sys Stbd Hyd Sys (1) Port Hyd Sys (2) Stored Energy Accum (Stbd Hyd Sys)	Stbd Hyd Sys Port Hyd Sys Stbd Hyd Sys

*Position Control (Except SS 572, 573)

**Rate Control (Except SSN 68 Class and TRIDENT)

561-1.4.2 AUTOMATIC STEERING CONTROL. An automatic Course Keeping Control (CKC) system was installed on most early nuclear submarines. For both surface and submerged operations, emphasis was placed on accurately holding a course under varying speed and weather conditions. In the CKC mode of operation, if the submarine deviated from an ordered course because of uncontrollable external forces, a signal was induced by movement of synchros associated with the compass and heading (course order transmitter). This error signal, amplified by magnetic or solid state amplifiers, controlled the rudder servo valve that positioned the rudder so as to return the ship to the ordered heading. This system continued to operate and hold a fixed heading until the control station called for a new course. On many of the more recently constructed ships, an Automatic Course Control (ACC) system is installed. This system, in addition to maintaining a heading, is capable of making course changes automatically when the course order transmitter is manually changed.

561-1.4.3 AUTOMATIC DEPTH CONTROL. An automatic Depth Keeping Control (DKC) system was installed on most early nuclear submarines. It is similar, with respect to both components and operation, to the CKC system, except that the error signal results from the variance between the depth registered by the ship's depth detector system and the ordered depth. Signal feedback for control action is from stern diving and fairwater planes. As the equipment limits the depth error signal, only small depth alterations can be made, enabling depth keeping but not significant depth change. More recent ships have an Automatic Depth Control (ADC) system that, in addition to maintaining constant depth, permits automatic compliance with any magnitude of depth change ordered.

561-1.4.4 COMBINED AUTOMATIC STEERING AND DIVING. Controllers combining the features of ACC and ADC are installed on the latest submarines.

561-1.4.4.1 Controller Operation. The controllers, referred to as Automatic Maneuvering Control (AMC), Automatic Submarine Control (ASC), and CONALOG, provide automatic control of the ship. Desired depth and course data are manually dialed into the controller, which provides control signals (similar to ACC and ADC units) to bring the ship to the ordered course and depth. The CONALOG system also provides a display that, in manual mode of operation, enables the helmsman to bring the ship to the ordered course and depth by pictorial or time-quickened display.

561-1.4.4.2 CONALOG Pictorial Display. A picture of the ship's status is synthesized at the ship's control panel on the display unit cathode ray tube before the outboard station. The view is one that helmsmen might have if they were supplied with a window facing out of the bow of a submarine. The ocean surface and bottom are represented by grid patterns that move toward the viewer as the submarine travels forward. The grid squares are compass-oriented to identify north; the squares vary in size to create an illusion of distance. Vertical and circular picture motions indicate ship trim and roll, while a center cross on the screen serves as the zero trim and heading reference. Command information is depicted as a roadway that the submarine must follow: the roadway curves to the port or starboard to indicate course errors, and changes height to indicate depth errors. Horizontal bars on the roadway move toward the observer to indicate relative ship speed.

561-1.5 SYSTEM OPERATING PRESSURE

561-1.5.1 As the size and speed of submarines have increased, the operating pressures of the steering and diving systems have increased correspondingly. On fleet submarines, systems have varied from 600 to 1,200 pounds per square inch (lb/in^2). The independent steering and diving systems on later submarines operate at pressures of 1,500 to 3,000 lb/in^2. As torque loads have increased with larger ships and higher speeds, 3,000-lb/in^2 systems have been used almost exclusively.

561-1.6 TYPICAL DIVING CONTROL SYSTEM

561-1.6.1 A typical stern plane hydraulic control system for SSN 637 and SSBN 640 Class submarines is shown in Figure 561-1-1. The figure incorporates a simplified electrical block diagram to show the relationship of components. The block labeled function generator primarily represents the electrical equipment associated with the automatic ship control feature. Fairwater diving and steering circuits are similar.

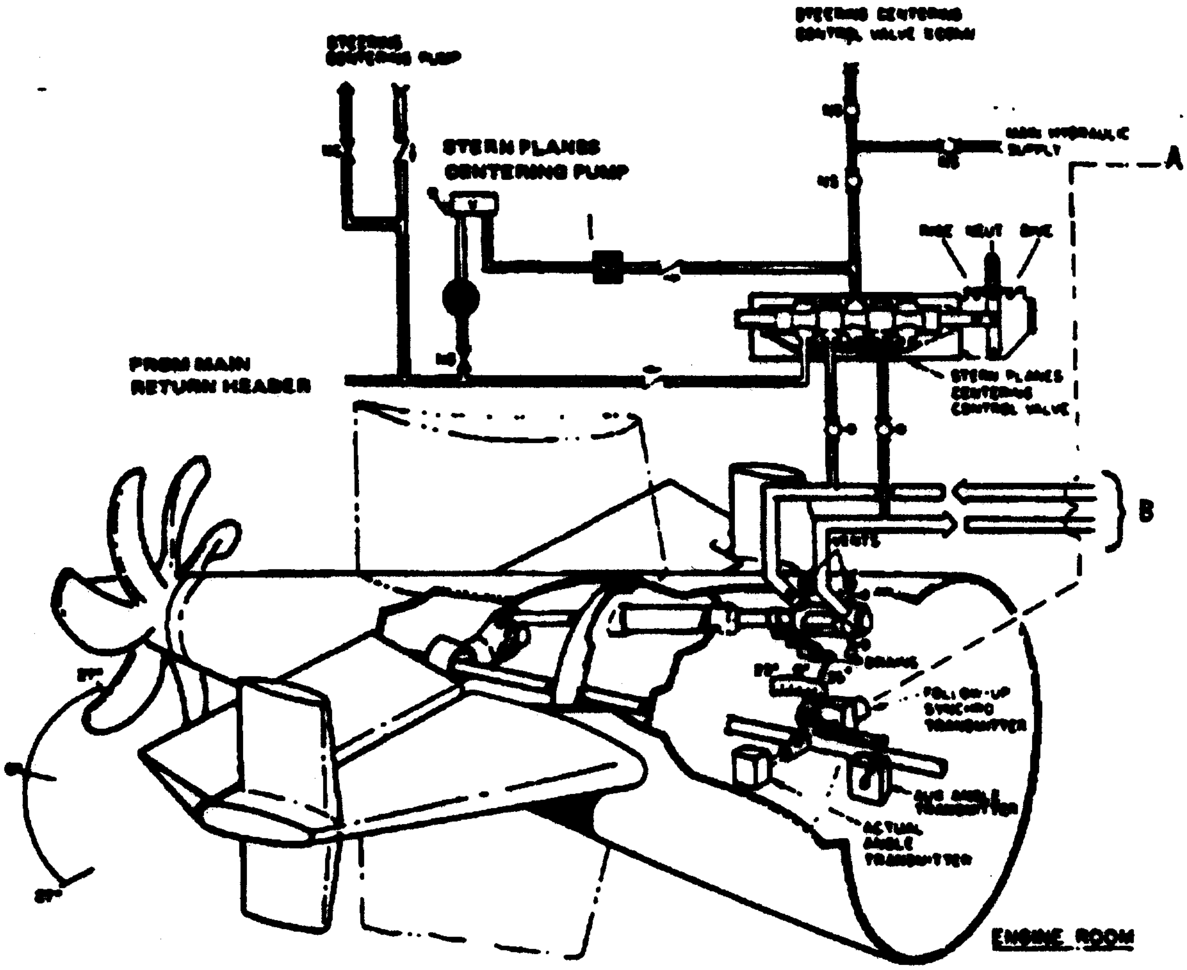


Figure 561-1-1. Typical Stern Diving Control System for SSN 637 and SSBN 640 Class (Sheet 1 of 2)

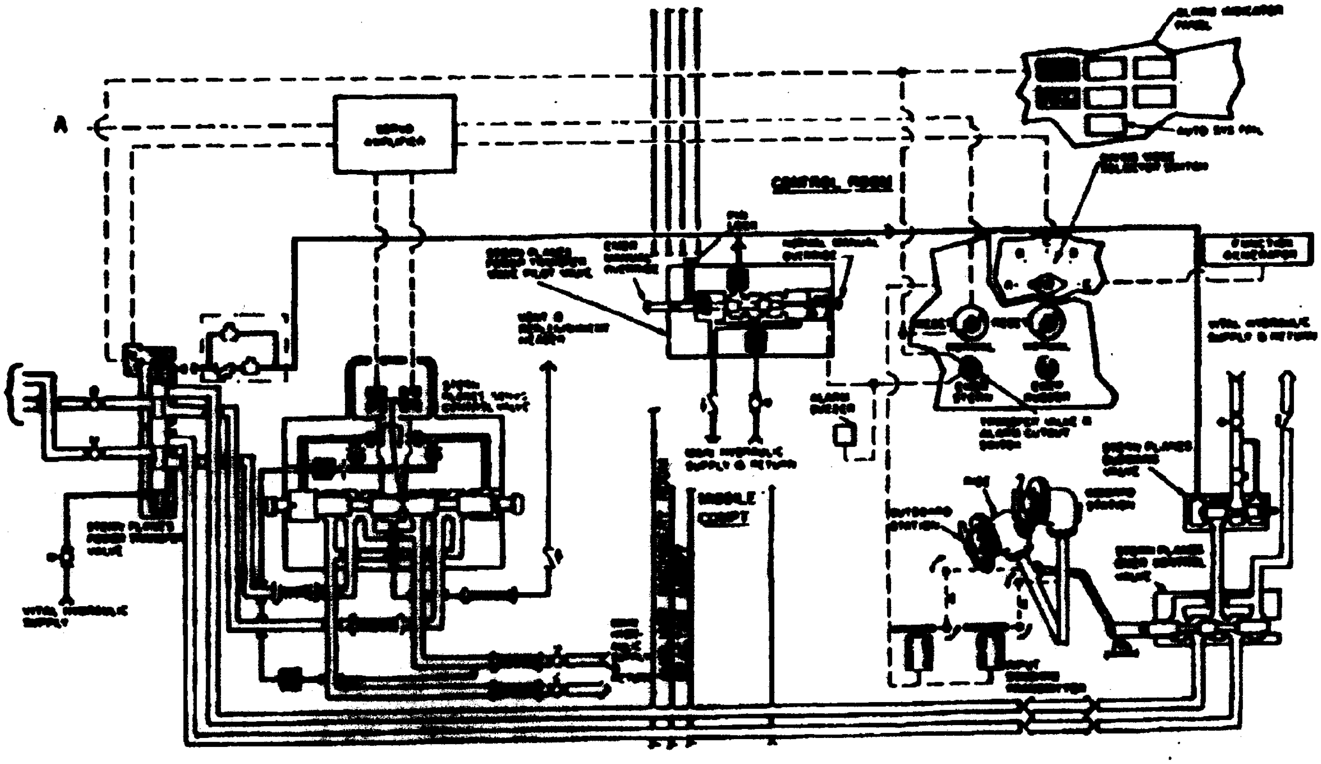


Figure 561-1-1. Typical Stern Diving Control System for SSN 637 and SSBN 640 Class (Sheet 2 of 2)

SECTION 2.

COMPONENTS: FUNCTION AND MAINTENANCE

561-2.1 CONTROL STATION COMPONENTS

561-2.1.1 GENERAL. Most submarine steering and diving control stations consist of an inboard and outboard operating station facing the ship control panel. Principal controls and indicators that are mounted on the ship control panel at a typical steering and diving control station are illustrated in Figure 561-2-1. Each operating station has an aircraft-type control column. Each wheel/column assembly consists of a control column, a wheel mounted on the control column, positioning devices, and three synchro resolvers.

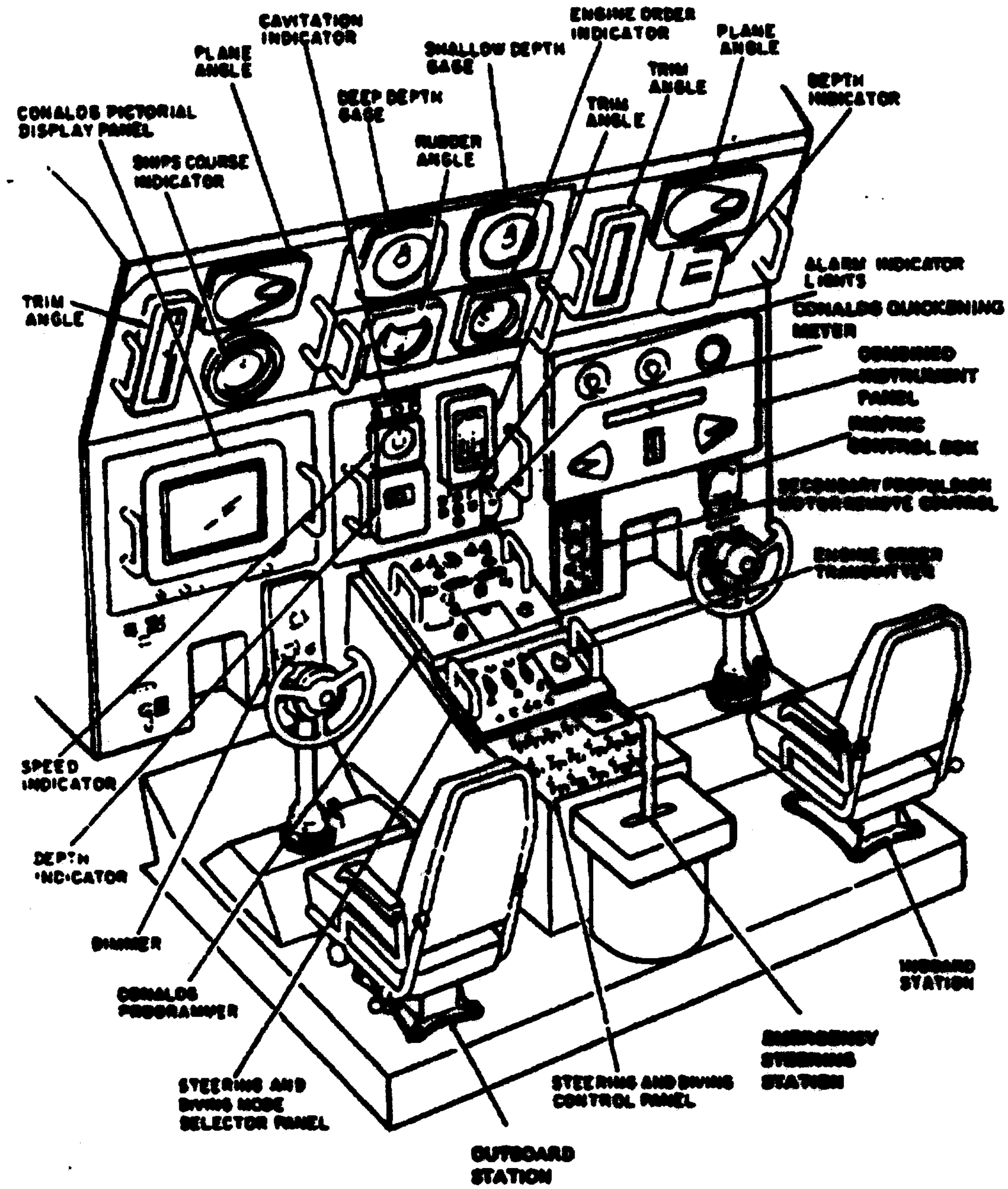


Figure 561-2-1. Typical Steering and Diving Control Station

561-2.1.2 WHEEL/COLUMN ASSEMBLIES. Stern diving planes and fairwater diving planes are controlled in both normal and emergency modes by fore-and-aft movement of the control columns. Pushing the control columns forward moves the planes in the dive direction. Pulling the controls aft moves the planes in the rise direction. Control column movement is limited to approximately 6 inches of travel forward (hard dive) or aft (hard rise) from its center position. Adjustable hard stops are provided at the full throw positions. These stops are used for initial system alinement by setting the maximum rise and dive angles for diving planes in the normal control mode.

561-2.1.2.1 Each control column is spring-loaded to provide a reactive force against movement by its operator. When the controls are released, spring action returns the control column to its center position. The force required to move a control forward or aft is nominally 10 pounds at center position, increasing to 20 pounds at full throw, and is adjustable.

561-2.1.2.2 Movement of the control column, which is pivoted at the base of the assembly, operates a gear train that rotates two synchro resolvers. Each synchro resolver, when energized, provides an electrical input signal to a servo translator amplifier. By switching arrangement, either the stern plane or fairwater plane translator servo amplifier, or both, may be connected to the synchro resolvers of either the inboard or outboard control column.

561-2.1.2.3 Each control column can be immobilized in one position by a pin-type lock. When secured with the lock, the control column is positioned for slight rise angle. This angle is determined for each ship during sea trials. To attain minimum drag on the hull during surface operation, the stern planes must be in the position that results from this ship-specific rise angle.

561-2.1.2.4 Emergency control-mode operation of stern diving planes and fairwater diving planes is controlled from the outboard and inboard wheel/column assemblies, respectively. Emergency control of the diving planes cannot be switched from one wheel/column assembly to the other. The outboard wheel/column assembly is mechanically linked to the emergency control valve for the stern diving planes. The inboard wheel/column assembly is mechanically linked to the emergency control valve for the fairwater diving planes.

561-2.1.2.5 Rudder surfaces are normally controlled by rotation of the wheel on either one or the other (but not both) of the column assemblies. For each 3-1/2 degrees of wheel rotation, the rudder moves 1 degree. Clockwise wheel rotation results in a right rudder movement; counterclockwise rotation produces a left rudder movement.

561-2.1.2.6 When rotated by the operator, the wheel positions a synchro resolver, which in turn generates an input signal for the rudder translator servo amplifier. By switching arrangement, the rudder translator servo amplifier may be selectively connected to the synchro resolver of either the inboard or outboard wheel. The wheel can be locked in its neutral position by a pin-type lock. Also, a drag force may be set on the wheel in any position from zero to lock. The drag force is adjusted by the rotation of a plate below the wheel; counterclockwise rotation increases the drag. Rotation of the drag plate sets a disc-type brake. The braking force is provided by a belleville washer. On the wheel shaft is a rack-operated stop and neutral detent device. The rack is spring-loaded to return the wheel to its neutral position (zero rudder angle), indicated by a spring-actuated detent. The force required to rotate the wheel, as measured tangentially at the rim, is nominally 1 pound at the center position, increasing to 5 pounds at maximum range of rotation. Also, adjustable hard stops are provided to limit movement of the rack, which in turn limits rotation of the wheel. These stops are used to aline the system initially by setting the maximum right and left rudder angle in the normal control mode.

561-2.1.2.7 In the normal control mode, the diving planes and the rudder can be operated from either the inboard or outboard wheel/column assembly, as selected by the position of a selector switch (or switches) located on the ship's control panel.

561-2.1.3 EMERGENCY STEERING STICK. Emergency rudder operation is accomplished by manually positioning the rudder emergency control value using the emergency steering stick located at the ship control station. The stick is spring-loaded so that, if released, it will return to the neutral, rudder-amidship position.

561-2.1.4 CONTROL COLUMN MAINTENANCE. When maintenance action is required on the control column assembly, the utmost care must be taken to ensure proper reassembly in accordance with applicable drawings. For example, with the original design on the SSN 571, SSN 578 Class, SSN 585/588 Class, SSN 586, SSN 597, SSN 598 Class, SSN 608 Class, SSBN 616 Class, and the SSBN 640 Class, it was possible to incorrectly assemble the pinion cam in an upside-down position. As a result of incorrect assembly, the stick could jam affecting both normal and emergency modes of operation for that stick. A pinion cam alteration to prevent incorrect assembly was authorized (SHIPALTs SSN 1579 and SSBN 1287). This example illustrates the necessity of verifying correct assembly. After control stick maintenance, the final action to complete the job should be an inspection of the stick and connecting linkages for ruggedness, for security of connecting pins, and for the presence of any interference that could jam the component.

561-2.2 SYNCHRO RESOLVERS

561-2.2.1 Basically, a synchro resolver (or control transformer) consists of a concentrically-alined wound rotor and stator that convert a mechanical position (angular rotation of the rotor shaft) into an output electrical signal by producing a variable magnetic coupling with the stator windings. The output voltage varies sinusoidally with the rotor position when the stator is excited. Shipboard use of synchro resolvers is described in paragraphs 561-2.2.2 and 561-2.2.3.

561-2.2.2 The steering and diving system generally uses nine synchro resolvers (transformers) that generate electrical signals for processing by the normal control mode circuitry. Six of the synchro resolvers are used to generate ordered rudder, stern plane, and fairwater plane angle signals; the remaining three are used to generate actual rudder, stern plane, and fairwater plane feedback signals. A limited number of ships have systems in which a common synchro resolver is used to generate ordered signals for the fairwater and stern planes. The total number of synchros on these ships is seven; four are for ordering signals and three are for feedback signals.

561-2.2.3 Synchro resolvers used in the steering and diving systems are not considered repairable by ship's force and should be replaced if they malfunction. The only tests that can be performed to troubleshoot a synchro resolver suspected to be a problem component are resistance-to-ground and continuity tests of the stator windings. Additional information on synchro resolvers is presented in NSTM Chapter 430, Interior Communication Installations.

561-2.3 TRANSLATOR SERVO AMPLIFIERS

561-2.3.1 The command signal for each servo control valve torque motor is supplied by a translator servo amplifier. Each amplifier processes signals both from a control stick command synchro resolver at the control station and from a feedback synchro resolver located in the vicinity of the control surface operating cylinder. In addition, each amplifier produces an output signal that operates the torque motor in a servo control valve. Operational characteristics are described in paragraphs 561-2.3.2 through 561-2.3.7.

561-2.3.2 Translator servo amplifiers have changed extensively since the beginning of nuclear submarine construction. In addition to the basic function of processing signals to control the servo valve, most translator amplifiers perform the second function of providing an automatic means to shift to the emergency control mode in the event of certain system failures. This second function is performed by the fail-detect network.

561-2.3.3 On earlier classes, the fail-detect network only monitored the translator amplifier for proper operation (internal failures). Through evolution, the function of the fail-detect network has greatly expanded. On SSN 688 and TRIDENT Class ships, the fail-detect network will automatically transfer from the normal control mode to the emergency control mode upon detection of any of the following failures:

a. Loss of electrical power to the amplifier

b. Loss of synchro excitation voltage

c. Failure in the amplifier network

d. Control surface movement in a wrong direction

e. Control surface movement at an improper rate

f. Excessive steady-state error between the ordered and actual control surface position

g. Control surface movement when no error signal is present.

561-2.3.4 In the event of any of the aforementioned failures, the fail-detect channel will interrupt power to the solenoid of the power transfer value pilot valve, causing it to shift to its emergency mode position.

561-2.3.5 The basic construction of these amplifiers has evolved from point-to-point wired magnetic amplifiers to solid-state amplifiers with plug-in modules.

561-2.3.6 Troubleshooting of all translator servo amplifiers, particularly older models, must be conducted cautiously. Improper technique can easily result in excessive damage. Damage to older amplifiers can be particularly expensive because of the high cost and scarcity of outdated components.

561-2.3.7 For detailed information and troubleshooting guidance, refer to applicable equipment technical manuals.

561-2.4 SERVO CONTROL VALVES

561-2.4.1 GENERAL. Servo control valves installed in submarine steering and diving systems can be classified into two general types. The most common type is the electrohydraulic servo valve that is used to control normal-mode steering and diving on most diesel submarines and on all nuclear submarines. The other type of servo valve, the hydraulic-mechanical servo valve, is used for emergency steering and diving modes on SSN 688 and TRIDENT Class submarines and for fairwater diving on SS 581.

561-2.4.2 ELECTROHYDRAULIC SERVO VALVES. The electrohydraulic servo valves used for steering and diving control are two-stage hydraulic control valves. An electrical input signal (the difference between command and feedback signals) results in a hydraulic flow output proportionate to the input signal.

561-2.4.2.1 SV-438-10P and SV-438-15P Servo Valves. SV-438-10-P and SV-438-15P valves were originally designed and built by Sanders Associates but are now being overhauled and built by Sargent Industries. The SV-438-10P valves are installed on most pre- SSN 678 Class submarines starting with the SSN 585/588 Class. The similar SV-438-15P valve is installed in SSN 678 through SSN 687. Five different configuration SV-438-10P valves were originally procured to match five existing electrical control interfaces. Subsequently, minor technical problems resulted in changes known as the viscous damper modification and the open orifice modification. In addition, some amplifier design changes by Electric Boat Division have resulted in torque motor wiring changes and three more configurations. Specifics regarding the possible valve configurations are addressed in the applicable servo valve technical manual (see paragraph 561-2.4.4).

561-2.4.2.1.1 The primary parts of the SV-438-10P and SV-438-15P low-noise electrohydraulic servo valves are shown in Figure 561-2-2. An input signal is applied to the servo valve torque motor adapter (now shown) from the translator servo amplifier. The torque motor adapter is required to match the amplifier to the servo valve torque motor (see paragraph 561-2.4.2.2). The torque motor produces an output torque that is proportional to the input signal current. The torque tube displaces the flapper valve between the nozzles of the pilot stage. This displacement causes an unbalance in pressure between PV1 and PV2 that moves the main control spool off center. Movement of the main spool continues until the feedback spring (wand) between the main spool and the flapper produces a torque equal and opposite to that produced by the torque motor. The spool displacement is therefore proportional to the input signal current. Accordingly, flow through the valve is proportional to input signal up to the point of maximum spool displacement. The maximum flow rate and, consequently, the ram rate, can be controlled either by setting the flow limiter adjustments to limit main spool travel or by limiting servo amplifier voltage output as discussed in paragraph 561-2.4.5.

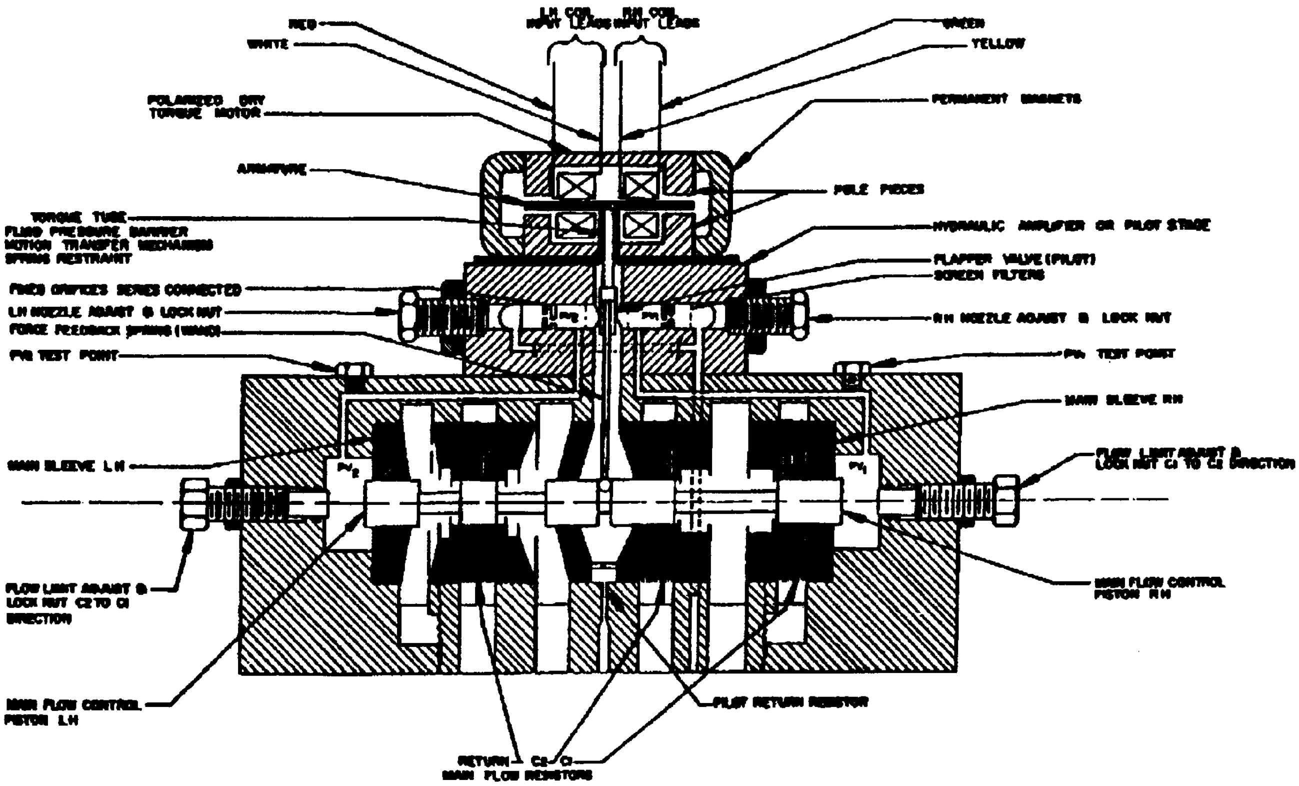


Figure 561-2-2. Servo Valve, Cross-Sectional View

CAUTION

Prior to the installation of a replacement servo valve, the valve shall be checked to ensure that the correct torque motor adapter is installed. Failure to use correct torque motor adapter may result in system malfunction.

561-2.4.2.2 SV-438-10P Torque Motor Adapter. When initially installed, each SV-438-10P valve was procured with a torque motor adapter configuration to suit the ship's control system amplifier. Any SV-438-10P valve configuration may be installed on any ship with SV-438-10P valves by rewiring the torque motor adapter to suit the ship's control system. Torque motor adapter removal, rewiring, and replacement procedures for each ship installation are provided in the servo valve technical manual (see paragraph 561-2.4.4).

561-2.4.2.3 Electrohydraulic Servo Valve Null Adjustment. Servo valves may be null adjusted on a test stand or with the valve installed in the ship. Null adjustment procedures are provided in servo technical manuals (see paragraph 561-2.4.4).

561-2.4.2.4 Bendix Valves. Functional drawings of the Bendix Corporation electrohydraulic servo valves used aboard the SSN 688 Class and TRIDENT Class ships are shown in Figure 561-2-3 and Figure 561-2-4 respectively.

561-2.4.2.4.1 In the SSN 688 Class valves, hydraulic operation of the first stage torque motor is achieved through the use of a flapper and two small nozzles. Hydraulic pilot pressure is applied to the two nozzle pressure chambers through a filter and two fixed orifices. When an input command signal is applied to the coils, the flapper moves from the null position, changing the gaps between the output ends of the two nozzles and the adjacent surfaces of the flapper. One gap is narrowed and the other is widened, resulting in an imbalance in nozzle chamber pressure. These pressure changes are transmitted to the second stage valve where they actuate the second stage valve spool. The drive piston receiving the higher pilot pressure begins to move the valve spool toward the opposite end and override the opposing centering-spring force, allowing spool movement. As the spool displaces from null system, hydraulic fluid is ported through the quieting elements in the sleeve. This allows system flow between the system hydraulic power source (ports P and R) and the associated ship's equipment (ports C1 and C2) being operated by the servo valve. The direction of flow is dependent on the polarity of the input command signal to the first-stage torque motor. The amount of spool travel, and hence the amount of fluid flow through the servo valve, is proportional to the amplitude of the input signal.

561-2.4.2.4.2 When the torque motor is at electrical null, the second-stage valve is at hydraulic null. All flow through the valve (ports P, R, C1, and C2) is blocked, except for allowable internal leakage. The second-stage valve spool is maintained at null (center position) by centering springs at each end and by balanced hydraulic pilot pressure applied to pressure chambers.

561-2.4.2.4.3 An adjustment nut and jamnut are installed at each end of the second-stage valve and used to null the valve spool with zero milliamperes of input current applied to the first-stage torque motor. The adjustment nut is used to position the associated drive cylinder inward or outward inside the bore of the end cap, increasing or decreasing centering spring tension on that end of the spool. A bolt threaded into the outboard end of each drive cylinder provides the means to adjust spool travel in each direction. A jamnut is installed on each bolt to lock the bolt at the selected position. By adjusting and locking the bolts, the flow rate through the servo valve is adjustable.

561-2.4.2.4.4 In the TRIDENT valves (Figure 561-2-4), the functioning of the first stage is the same as for the SSN 688 Class valves except that second stage spool positioning control is different.

561-2.4.2.4.5 Linear Variable Differential Transformers (LVDTs) (hereinafter referred to as transducers) threaded into the outboard end of each drive cylinder provide a means of sensing and controlling the valve spool position. Transducer output, resulting from valve spool motion in either direction, is fed to the ship system electronics where it is used to control the electrical command to the torque motor. The second-stage valve is operated by internal pilot differential pressures created by operation of the first-stage torque motor. When the torque motor is at electrical null, the second-stage valve is at hydraulic null, and the transducers are at electrical null, with all flow through the valve (ports P, R, C1, and C2) blocked. The second-stage valve spool is maintained at null (center position) by transducer feedback, by centering springs at each end, and by balanced hydraulic pilot pressure applied to pressure chambers in drive cylinders also located at each end.

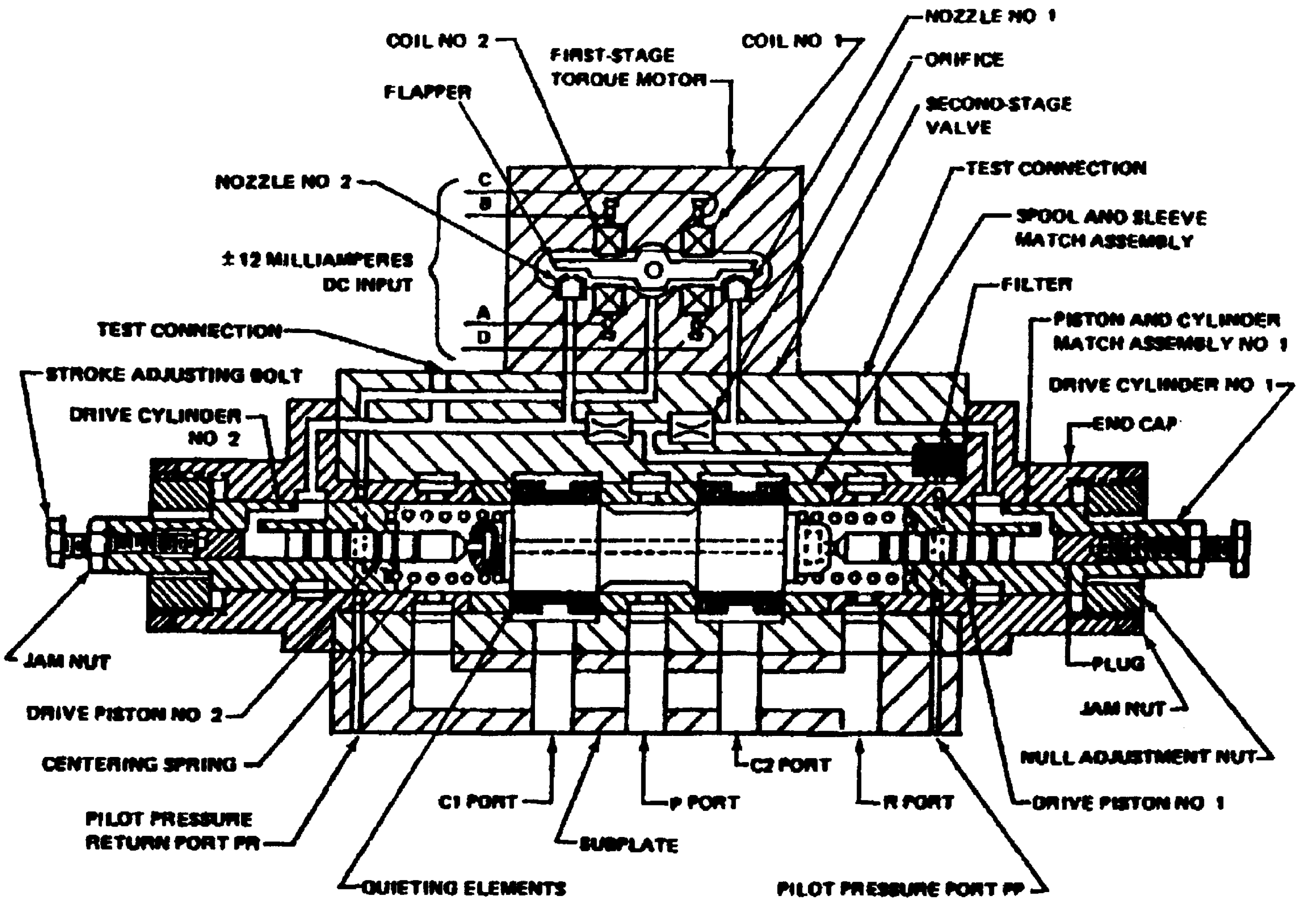


Figure 561-2-3. SSN 688 Servo Valve, Functional Diagram

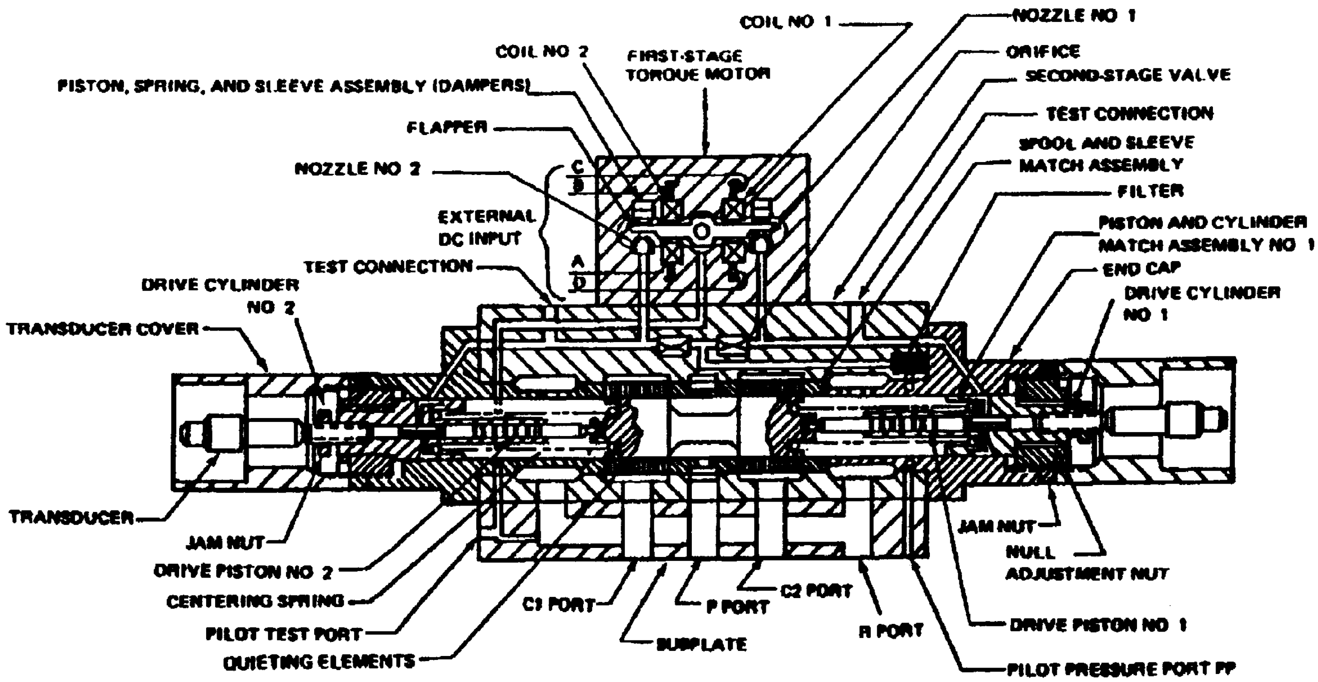


Figure 561-2-4. TRIDENT Class Servo Valve, Functional Diagram

561-2.4.2.4.6 When the first-stage torque motor receives an input command signal, the nozzle chamber pressures in the first stage become unbalanced. As a result, a pressure differential is created between the two drive-cylinder pressure chambers in the second-stage valve. The drive piston receiving the higher pilot pressure will begin to move the valve spool toward the opposite end where the pilot pressure is being ported to pilot pressure return through the first-stage torque motor nozzle block. The increased pressure in the small pressure chamber of the drive cylinder and drive piston also overrides the opposing centering-spring force, allowing spool movement. Spool movement causes transducer output to the ship's system in a feedback loop to control and maintain spool position to the commanded position. As the spool displaces from null, system hydraulic fluid is ported through the quieting elements in the sleeve. This allows system flow between the system hydraulic power source (ports P and R) and the associated ship's equipment (ports C1 and C2) being operated by the servo valve. The direction of flow is dependent on the polarity of the input command signal to the first-stage torque motor. The amount of spool travel is linearly proportional to the amplitude of the input signal, and flow through the valve is controlled electronically instead of by spool stops as discussed in the preceding description. An adjustment nut and jamnut are installed at each end of the second-stage valve and are used to null the valve spool with zero milliampere of input current applied to the first-stage torque motor. The adjustment nut is used to position the associated drive cylinder inward or outward inside the bore of the end cap, increasing or decreasing centering spring tension on that end of the spool. It must be clearly realized that this adjustment is a null adjustment only and not a spool stop to limit maximum flow through the servo valve.

561-2.4.3 MECHANICAL-HYDRAULIC SERVO VALVE. The mechanical-hydraulic servo valve receives input through hydraulic lines. In SSN 688 Class, a master cylinder is moved by the control column or wheel proportional to the ordered control surface position. Fluid from the master cylinder, in turn, moves the slave cylinder at the servo valve commensurate with the ordered control surface position. In the TRIDENT valve, the procedure is similar except that the slave cylinder displacement is dependent upon a pressure signal that is proportional to the displacement of a pilot valve at the control station. In both SSN 688 and TRIDENT Classes, there is mechanical feedback input to the valve as the control surface moves to its ordered position. The summing linkage at the valve returns the emergency control valve spool to the blocked neutral position when the control surface reaches the ordered angle.

561-2.4.3.1 SSN 688 Class - Bendix Mechanical-Hydraulic Servo Valve. A schematic of the SSN 688 Class mechanical-hydraulic servo system is shown in Figure 561-2-5. Movement of the control column or stick produces a mechanical input signal by positioning the master cylinder piston. The position of the master cylinder piston is always proportional to the ordered control surface position. The master cylinder piston displacement causes a hydraulic fluid displacement that is transmitted via piping to the slave cylinder in the emergency control unit assembly. This displacement of the slave cylinder causes the pilot and main stage spools of the emergency control valve to shift, porting pressure to the control surface operating cylinder. As the control surface moves, the emergency follow up and transmitter drive linkage attached to the operating rod coupling is driven. The feedback linkage transmits a mechanical signal to the emergency control unit assembly, which causes the emergency control valve spool to return to the blocked center position when the control surface reaches the ordered angle. As long as the control column is held at the ordered position, the control surface will also hold its respective position. With this system, control surface movement rate is maintained by a pressure-compensated flow-control valve located in the return line from the emergency control valve.

561-2.4.3.2 TRIDENT Class - Sargent Mechanical-Hydraulic Servo Valve. A schematic of the TRIDENT Class mechanical-hydraulic servo system is shown in Figure 561-2-6.

561-2.4.3.2.1 Each control surface control system input signal generator consists of two three-way, infinite positioning, proportional control valves within a common body. The valves are operated in conjunction with each other by the control column or emergency helm. When a control column or the emergency helm is deflected, the spools of both valves in the input signal generator are displaced from the blocked center position. One of the spools is positioned to allow pressurized hydraulic fluid to be supplied to the slave cylinder of the emergency control valve, while the other spool is positioned to vent fluid from the opposite end of the slave cylinder.

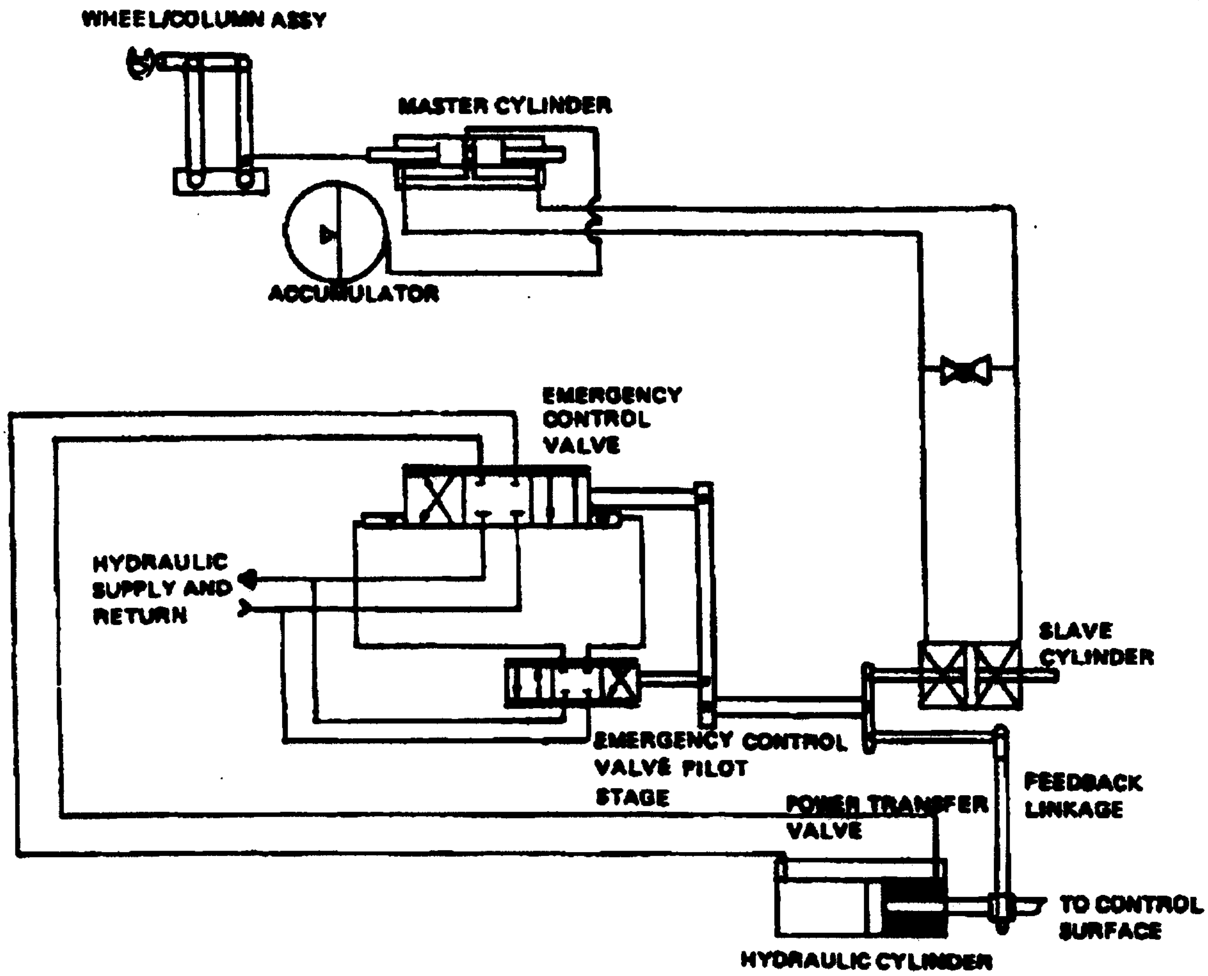


Figure 561-2-5. SSN 688 Class Mechanical-Hydraulic Servo System (Emergency Mode)

561-2.4.3.2.2 The spool of each valve in the input signal generator is spring-loaded on one end and has a hydraulic pilot actuator on the opposite end. The interaction of the spring and the hydraulic pressure on the pilot actuator causes the valves to remain open only until the hydraulic pressure balances the spring pressure applied when the control or emergency helm is deflected. This hydraulic fluid pressure is the control surface hydraulic position command signal sent to the emergency control valve.

561-2.4.3.2.3 The emergency control valve assembly consists of a slave cylinder, two directional control valves, a boost cylinder with associated cross-port relief valve, and the interconnecting summing linkage. The hydraulic input signal to the emergency control valve is applied to the slave cylinder. Displacement of the slave cylinder piston causes the movement of the summing linkage input arm to shift the pilot valve spool.

561-2.4.3.2.4 Hydraulic fluid is ported through the pilot valve to the boost cylinder, causing movement of the piston (which is pinned to both the input arm and the feedback arm of the summing linkage). Movement of the piston in the boost cylinder causes displacement of both the input arm and the feedback arm. When the piston of the boost cylinder reaches a position corresponding to the desired control surface angle, the pilot valve spool will be at the blocked center position, thus holding the piston of the boost cylinder at the desired position. At the same time, displacement of the feedback arm (connected to the opposite end of the boost cylinder piston) causes the main stage spool to be positioned so as to allow pressurized hydraulic fluid to be supplied to the control surface ram via the power transfer valve. As the control surface ram moves, the feedback arm is displaced, thus returning the main stage spool to the blocked center position. When the ram reaches the desired position, the main stage spool is at the blocked position; and ram motion stops. With this system, control surface movement rate is controlled by adjustable mechanical stops on the main stage spool extension.

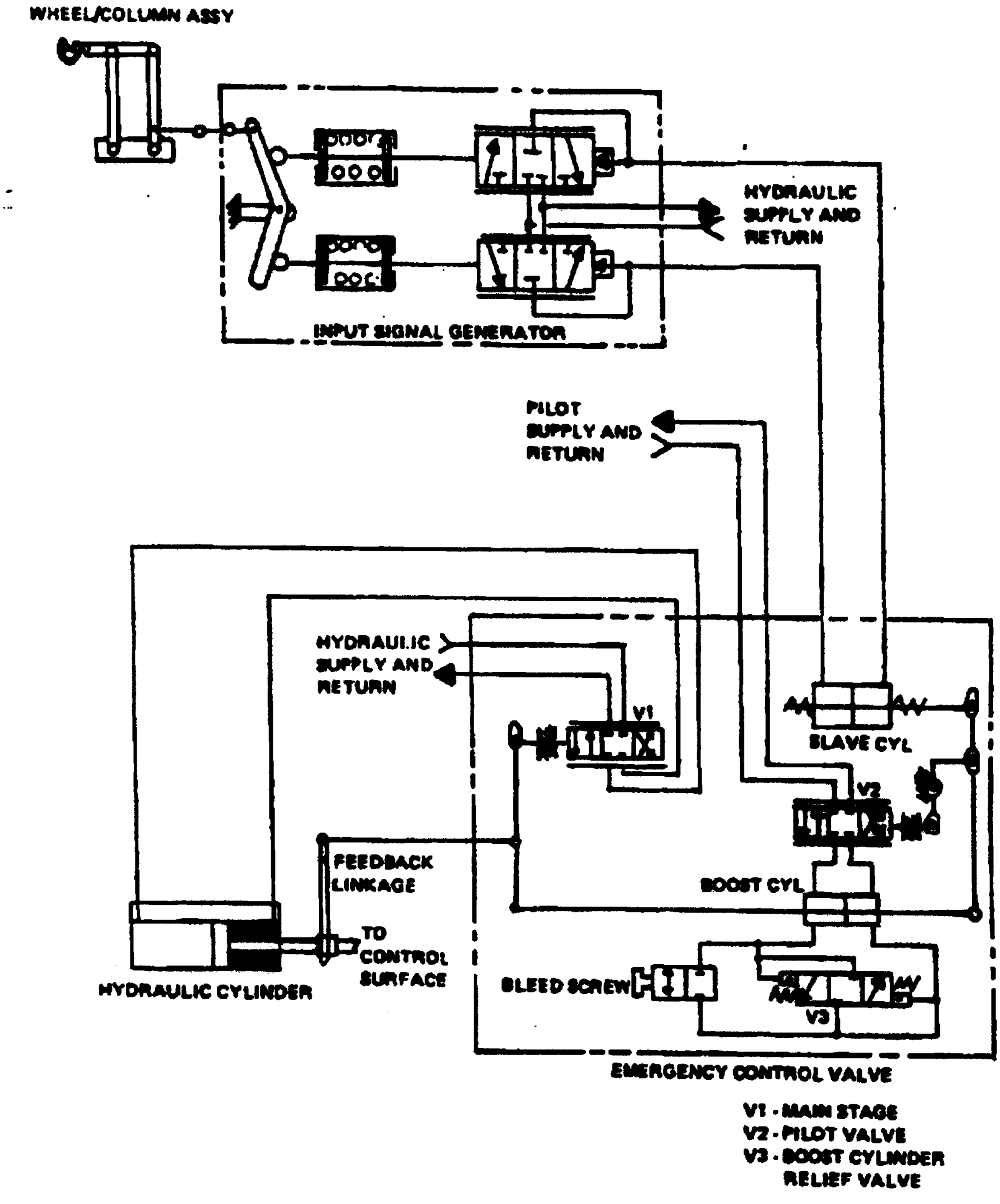


Figure 561-2-6. TRIDENT Class Mechanical-Hydraulic Servo System (Emergency Mode)

561-2.4.4 REFERENCE MANUALS. Each model servo valve installed in submarine steering and diving systems has an individual technical manual. The servo valve model installed in each ship or ship class, along with its corresponding technical manual number, is identified in Table 561-2-1. Applicability of manuals should always be verified using the most current ships' technical manual index.

Table 561-2-1 SERVO VALVE APPLICABILITY

Ship Number	**Manufacturer and Manufacturer's Part Number**	**NAVSEA Technical Manual Number**
AGSS 555	Arkwin 7A 038	0322-LP-037-5010
SS 567	Bendix Electrodynamics 3167240	
LPSS 574	(Stern) Sperry 1675441-2	0905-LP-075-3020 Appendix B
LPSS 574	(Rudder) Sperry 1675441-4	0905-LP-075-3020
LPSS 574	(Bow) Sperry 1675441-1	0905-LP-075-3020
SS 576, 580 SSN 575, 578, 583, 584	Sanders Associates SA-22	0348-LP-137-9000
SS 581	(Stern, Rudder) Bendix Corporation 3060254	0321-LP-005-8000
SS 581	(Fairwater) Sanders Associates (Mechanical-Hydraulic) SV-437	0905-LP-000-4420
SS 582, SSN 579	Bendix Electrodynamics 3060254	0321-LP-005-8000
SSN 585 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 594 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 597	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 598 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 608 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 616 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 640 Class	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 637-677	Sargent Industries* SV-438-10P	S9561-AQ-MMA-010/SV-438-10P
SSN 678-687	Sargent Industries* SV-438-15P	0922-LP-030-4010
SSN 688 Class Normal Mode	Bendix Electrodynamics 3188615-1	0948-LP-035-9010
SSN 688 Class Emergency Mode	Bendix Electrodynamics 3188610	0948-LP-113-4010
SSBN 726 Class Normal Mode	Bendix Electrodynamics 3311731	S6435-AB-MMA-010/PN3311731
SSBN 726 Class Emergency Mode	Sargent Industries	**

*Originally manufactured by Sanders Associates

**Identify using ship Technical Manual Index

561-2.4.5 FLOW RATE ADJUSTMENT. With most servo valves, the maximum desired control surface rate is reached with less than maximum valve spool displacement. Therefore, one of the following techniques is used to limit the rate to some selected maximum level. (See paragraphs 561-3.1.1 and 561-3.2.1 for specific rates.)

a. Physical hardstops (within the valve) are used to limit the servo valve main spool displacement.

b. The servo amplifier electrical output is limited to the value required to produce the desired flow rate through the servo valve.

1. A flow control valve is installed in the hydraulic piping to limit flow rate. Generally, the third method has been used in the past. However, when the low-noise servo valves were backfitted, the valves were designed with flow limiters (adjustable spool stops) and the flow control valves were removed from the hydraulic system because of their potential contribution to noise. Of those on the newer ships, SSN 688 class emergency mode is the only servo system that uses a flow control valve.

561-2.4.5.1 Rate Adjustment Using Valve Flow Limiters. On some of the earlier submarine classes, the only adjustment by which the maximum ram rate is controlled is that to the servo valve main spool displacement hardstops. The procedure to be followed to adjust the rate is provided in the servo valve technical manual identified in Table 561-2-1. In most cases, these ships have the model SV-438-10P electrohydraulic servo valve installed. An exception to the above is the TRIDENT Class emergency control valve. This valve also uses flow limiters and is to be adjusted in accordance with its own technical manual.

561-2.4.5.2 Rate Adjustment Involving Servo Amplifiers. On most ships the maximum ram rate is adjusted by both setting the servo amplifier output and using the servo valve main spool displacement hardstops. This adjustment procedure is provided in the applicable servo valve technical manual, which will reference the servo amplifier technical manual as required. The TRIDENT normal mode electrohydraulic servo valve is a slight exception in that the rate is set and controlled entirely by the amplifier (or Position Control Unit). The servo valve technical manual need only be referred to if the valve null requires adjustment.

561-2.4.6 SERVO VALVE REPAIR. Because servo valves are fairly complex devices, repair should not be attempted by untrained personnel. Many valves have been damaged by improper disassembly by forces afloat. Any maintenance or repair work should be accomplished in accordance with, and only after careful study of, the applicable technical manual.

561-2.4.6.1 Shipboard Repair. Because most ships are provided with one or two spare servo valves, complete replacement of a malfunctioning servo valve with a spare valve is generally the preferred maintenance action. On some ships, repair parts are carried as spares, making possible to replace a troublesome component or the pilot stage assembly. Under normal circumstances, only trained personnel should undertake replacement, following step-by-step the procedures and precautions in the applicable technical manual.

561-2.4.6.2 Depot Level Repair. In that onboard repair of servo valves is generally limited to minor adjustments, servo valves will normally be repaired at tender or depot levels where trained personnel and test stand facilities are available.

561-2.4.6.3 Test Stands and Equipment. The equipment required to perform null adjustments, overhaul maintenance, and performance testing on a test stand is listed in servo valve technical manuals. This equipment is considered necessary for making a complete valve overhaul. However, for the most part, those tests required for valve maintenance can be made with less test-stand capability than that indicated in the technical manual. When servo valves are tested on a test stand with less than rated flow capacity, the flow limiters on the main stage should be adjusted so that the maximum flow rate through the valve will not exceed the test-stand capacity.

561-2.4.6.4 Servo Valve Filter Maintenance. Most of the steering and diving servo valve installations are equipped with filters to protect at least the pilot stage of the valve. Usually an external filter is installed in the pilot supply line and many of the servo valves are equipped with an additional internal filter. One of the most common causes for servo valve malfunction is a dirty filter that is preventing adequate flow to the pilot stage. Because this is the case, filter element maintenance should be accomplished prior to other repair or maintenance actions when servo valves are malfunctioning. External filters should be checked prior to removal of internal filters.

561-2.4.6.5 External Filters. Detailed guidance on the maintenance and cleaning (if applicable) of hydraulic filter elements, including required stock numbers, is provided in **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** . The following factors often result in contaminants passing through the element and causing servo valve problems and should be forestalled by proper procedures and sound preventive maintenance, as indicated:

1. Infrequent element replacement. Differential pressure indicators are provided to signal maintenance need. Failure to respond to this signal causes higher differential pressures across the element, which may force contaminated fluid past O-ring seals.
2. Failure to install filter element. Under certain shipboard conditions such as lack of onboard spares and inadequate cleaning facilities, there is a temptation to assemble a filter housing which may have been improperly assembled without the element in spite of a requirement that filter elements must always be installed.
3. Installation of a damaged element. Repeated usage or rough handling can easily damage filter elements; this damaged condition, which may not be readily apparent, will allow passage of large particles through the element. Cleanable elements should be bubble-point tested prior to reuse after cleaning, as described in **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** .
4. Ultrasonic cleaning of noncleanable elements. Noncleanable elements can physically resemble cleanable elements and may be damaged as a result of inadvertent ultrasonic cleaning. Noncleanable elements conforming to MIL-P-8815 for these applications will be marked NONCLEANABLE; however, some interchangeable proprietary elements may not carry such markings. Elements that are cleanable should be marked CLEANABLE. Use of noncleanable elements is recommended whenever possible.
5. Inadequate cleaning of elements. Many of the installed cleanable elements can be particularly difficult to clean, even by highly trained personnel under ideal conditions. Furthermore, the dirt capacity of these elements is generally small. Failure to restore elements to an as-new condition will result in high differential pressures in a short operating time, requiring maintenance as frequently as daily. These elements should be discarded. **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** , provides filter element cleaning procedures.
6. Damaged or missing O-ring seals. Excessive temperatures, rough handling, or repeated use can lead to deterioration of the O-ring seals. Satisfactory O-rings are required to seal both the element and an automatic cutoff diaphragm which is a special feature commonly incorporated in these filter housings. Defective O-rings allow leakage and pressure loss of the filter elements.
7. Improper filter housing installation. Inlet and outlet ports are identical; therefore it is possible to install the housing in reverse even though the ports are generally stamped IN and OUT. The resulting reverse flow through the housing can ruin the element, washing both trapped dirt and filter material into downstream components.
8. Improper filter elements installation. Filter elements may have been installed upside down in a filter bowl, providing no filtration. Proper installation requires that the closed end of the element be at the bottom of the filter bowl and that the open end fit up into the mating area of the filter head. Furthermore, the bottom of these filter elements is usually provided with a bellville washer or similar spring assembly to keep the element seated when installed. Removal of these spring assemblies allows fluid to bypass the element.

9. Improper maintenance procedures. Upon insertion of a new element into a filter bowl prior to reassembly, the bowl and element should be filled with oil to minimize air entrainments and associated hazards upon repressurization. The previously drained oil, or other contaminated oil, shall not be poured into the element, since this oil and dirt will reach downstream components. Only clean system fluid shall be used.

561-2.4.6.6 Internal Filters. Because all servo valves do not have internal filters and some filters cannot be readily maintained, the appropriate servo valve technical manual should be consulted for filter maintenance procedures. Internal screens are installed in some configurations of the SV-438-10P and SV-438-15P servo valves, but maintenance and replacement must be accomplished by trained personnel. Most Bendix servo valves have cleanable internal filters. These may be cleaned using the procedure in the servo valve technical manual if maintenance of the external filter does not correct servo valve operation.

561-2.5 POWER TRANSFER VALVES

561-2.5.1 GENERAL. Control systems for fairwater diving planes, stern diving planes, and the rudder each utilize a power transfer valve.

561-2.5.2 FUNCTIONAL DESCRIPTION. Power transfer valves are six-way, two-position spool-and-sleeve-designed directional control valves. Pilot pressure for actuating the valve spool is supplied to the chambers at each end of the spool. One end of the spool is supplied from the normal control mode hydraulic system via a solenoid-operated pilot valve; the other end is supplied by the emergency control mode hydraulic system.

561-2.5.2.1 An imbalance in the effective end areas of the spool normally causes the spool to be shifted to its normal control mode position, allowing pressurized fluid from the normal mode hydraulic system to be ported to the control surface hydraulic cylinder. When the pressure on the normal control mode (larger) end of the spool is relieved, the spool shifts to the emergency control mode position and allows fluid from the emergency control mode hydraulic system to be ported to the control surface hydraulic cylinder.

561-2.5.2.2 A limit switch, an integral part of the valve, is actuated by the valve spool when the spool shifts to its emergency mode position. The limit switch contacts then energize the circuits to the emergency mode indicator light and the audible alarm buzzer, while deenergizing the circuits to the power transfer valve pilot valve solenoid and the normal mode indicator light.

561-2.5.2.3 On SSN 688 Class ships, the stern diving plane and rudder power transfer valves are mounted directly adjacent to their hydraulic cylinders, which have integral porting for the hydraulic fluid. The fairwater diving plane power transfer valve is located inside the pressure hull and is connected by appropriate piping to the fairwater diving plane hydraulic cylinder in the bridge access trunk in the sail.

561-2.5.3 INSTALLATION AND ASSEMBLY. Mechanical failure of the power transfer valve will result in loss of both normal and emergency control modes. Therefore, particular attention shall be given to verification of proper assembly and installation. When valves or attaching flanges are assembled, the proper torque must be applied evenly to all fasteners to prevent overloading and resultant failure of one or more of the fasteners. Of prime concern are the fasteners that function to secure: the end caps to the valve body; the pipe flanges to the subplate or valve, depending upon the specific design; and the valve body to the subplate or cylinder, if so designed. During each reassembly, these fasteners must be uniformly torqued to the precise values given on applicable assembly drawings. If values are not listed on drawings, general torque values for fasteners can be obtained from **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** .

561-2.5.4 POWER TRANSFER VALVE PILOT VALVES. The control systems for the rudder, stern diving planes, and fairwater diving planes each have their own solenoid-operated power transfer valve pilot valve that serves to position the power transfer valve spools.

561-2.5.4.1 The power transfer valve pilot valve for each control surface provides the means by which the operator, or the electrical control system, can initiate a shift of the power transfer valve. The power transfer valve pilot valve makes this shift by venting the power transfer valve normal supply pilot line in response to an interruption of electrical power to its solenoid or in response to a manual override operation.

561-2.5.4.2 The power transfer valve pilot valve is generally a three-way, two-position solenoid-controlled control valve. It is of a spool-and-sleeve design, normally electrically controlled in one direction, but able to be manually operated by an override. The valve is spring-loaded to shift to the other operating position whenever the solenoid is deenergized.

561-2.5.4.3 When the solenoid is energized, the valve spool shifts to permit hydraulic fluid from the normal control mode supply to pressurize the large end of the power transfer valve spool, keeping the power transfer valve in its normal mode position. When the solenoid is deenergized, the pilot valve relieves the fluid pressure on the large end of the power transfer valve spool by porting it to the normal control mode return, permitting the power transfer valve to shift to its emergency mode position. The pilot valve can also be pin-locked in this latter position to hold the power transfer valve in its emergency mode position. The failure-detection circuit monitoring the control surface action initiates the automatic shift to emergency by interrupting power to the applicable power transfer pilot valve solenoid under any of the applicable fail-detect conditions previously discussed. Power to the solenoid can be manually interrupted by shifting the associated mode selector switch to the emergency position.

561-2.6 CONTROL SURFACE ANGLE INDICATION SYSTEMS

561-2.6.1 GENERAL. In most submarine installations, the following three independent angle-indication systems are provided:

1. Normal
2. Auxiliary
3. Mechanical

561-2.6.2 NORMAL ANGLE INDICATION. The rudder, fairwater/bow plane, and stern plane angle indicator systems (IC circuits N, NB, and NS, respectively) generate control surface position signals to position rudder and plane angle indicators on the ship control panel. Actual rudder angle is generally repeated on the portable bridge IC control unit, if provided. The indicators are positioned as stated in paragraph 561-2.6.2.1.

561-2.6.2.1 IC circuits N, NB, and NS each contain a synchro transmitter that is mechanically linked to the hydraulic ram of the associated control circuit. The magnitude and phase of signals transmitted are determined by the angular relationship of the rotor and stator of the synchro transmitter. The angle signals are converted by synchro receivers at the ship control station to angle indication. Circuits N, NB, and NS generally utilize 120-volt 60-Hz single-phase AC power.

561-2.6.3 AUXILIARY ANGLE INDICATION. Auxiliary circuits XN, XNB, and XNS provide supplementary indication of the approximate angle (within 5 degrees) of the rudder, fairwater/bow planes, and the stern planes by lighting numerals on the perimeters of the combined normal and auxiliary rudder and plane angle indicators on the ship control panel. If one of the normal circuits becomes inoperative, the auxiliary circuit continues to provide approximate angle indication. Both normal and auxiliary circuits are energized when the ship is underway. Operation is as follows:

561-2.6.3.1 IC circuits XN, XNB, and XNS each contain a circuit-making transmitter that is mechanically linked to the hydraulic ram of the associated control surface. Each transmitter consists of a contact arm and several contact buttons that are wired to the indicating lights on the angle indicators at the ship control station.

561-2.6.3.2 Circuits XN, XNB, and XNS are generally powered by 120-volt AC stepped down by a 120/6-volt transformer that supplies 6 volts AC to the transmitter. If the 6-volt AC supply fails, an automatic shift to a 6-volt DC dry cell battery source occurs.

561-2.6.4 MECHANICAL ANGLE INDICATORS. Generally, the mechanical indicators for the rudder and stern diving planes each consist of a bar engraved in 1-degree increments corresponding to the particular control surface actual angular positions. The engraved bar is mounted parallel to the control surface operating rod. An indicating pointer is attached to the control surface operating rod. Movement of the operating rod causes the pointer to move along the engraved bar, indicating the angular positions of the particular control surface. After all adjustments have been made to the system, the angular positions are scribed on the bar by setting the control surface to a specific angle and scribing the indicator bar to match. Thus, the mechanical indicators can be used as a reference for the rudder and stern diving plane actual angular position and can be used to aline the angle transmitters and auxiliary angle transmitters. The description in paragraphs 561-2.6.4.1 through 561-2.6.4.4 is applicable as indicated.

561-2.6.4.1 General. Typically, the mechanical indicator for the fairwater diving planes is part of the fairwater diving plane feedback drive gear assembly. The input shaft to the bevel gears of the feedback drive gear assembly is extended, and a pointer is attached to the end of the extended shaft. The pointer rotates to indicate the angular positions of the fairwater diving planes. The indicator plate is scribed in 1-degree increments corresponding to the actual angular positions of the fairwater diving planes. The scribing is done after final adjustments have been made to the system and, therefore, indicates the exact angular positions of the fairwater diving planes.

561-2.6.4.2 Control Surface Angle Reference. Each mechanical indicator is located within sight of its respective local manual control valve, thereby affording the operator an immediate control surface angle reference.

561-2.6.4.3 Inspection Procedures. The fairwater diving plane feedback drive gear installed aboard SSN 598, 608, and SSBN 616, and 640 Class ships requires special attention because of the basic design. The mechanical indicator and feedback transmitters are driven by a long rod (indicating linkage) that penetrates the pressure hull between the bridge access trunk and control room. Periodically, when other maintenance is performed in the general area, inspect the linkage as follows:

1. Examine all linkage for straightness and conformance to applicable assembly drawings and detail drawing listed thereon.
2. Examine linkage installation for any obstruction that would interfere with, or contact, the linkage during normal linkage motion.
3. Check the linkage orientation. All linkage pins should be parallel to one another with their axes oriented as shown on the applicable assembly drawing.

4. Check the bearings at the ends of the individual links for corrosion or binding; lubricate, rework, or replace as required.

5. Check the link passing through the pressure hull stuffing box for binding, chattering, or noisy operation during movement of the fairwater planes. Observe inside the pressure hull and the bridge access trunk. Any of the aforementioned symptoms may indicate a buildup of dried out, caked grease in the V-ring stuffing box or rod bushing.

561-2.6.4.4 Corrective Action. When discrepancies are uncovered during inspection, take corrective action as follows:

CAUTION

During disassembly, the exact position of all pieces should be noted and the exact number of turns to remove rod end bearings recorded because the feedback synchros are readily rendered out of proper adjustment if not properly reassembled

1. Remove the link passing through the pressure hull stuffing box. Unbolt and remove the V-type packing gland. Unbolt and remove the stuffing box bushing. Because this bushing does not unbolt on the SSN 598 Class, do not attempt to remove it on this class ship. Remove V-ring packing and any hardened grease in the stuffing box. It is advisable to install new V-rings; however, under conditions requiring expediency, if the old rings appear adequate, they may be reinstalled. Lubricate the entire surface of each V-ring component with MIL-L-17331 fluid (MS 2190TEP) and install packing in accordance with **NSTM Chapter 078, Seals** .

2. Reassemble gland and linkage. Using grease conforming to MIL-G-24139 grease the gland through the grease fitting. MIL-G-24139 grease is available in the stock system in the following quantities:
   a. 1-pound container (NSN 9150-00-180-6381)
   b. 5-pound (NSN 9150-00-180-6382)
   c. 35-pound (NSN 9150-00-180-6383)

3. Verify that the feedback synchros, plane angle transmitters, and mechanical angle indicator are functioning properly by cycling the planes in normal mode and observing and comparing performance and electrical and mechanical angle indication to the specific ship requirements. Hard stop, rise, and dive angle indication in emergency mode operation should also be checked. The adjustment procedure, if required, is generally provided on applicable fairwater diving gear follow-up and transmitter drive assembly drawings.

561-2.6.4.5 Inspection of Angle Indicator and Feedback Transmitters. On all submarines, whenever work is accomplished in the vicinity of the rudder, stern diving, or fairwater/bow diving feedback transmitter linkages, the activating linkages should be inspected for ruggedness, proper clamps, presence of set screws, and security of connecting pins. If bolts are used in these systems for connecting linkages of securing vital components, they shall be installed in a position such that a loss of the nut will not permit the bolt to fall out as a result of gravitational forces.

561-2.7 STEERING AND DIVING HYDRAULIC CYLINDERS

561-2.7.1 OVERVIEW. Each control surface (fairwater/bow plane, stern plane, and rudder) is driven by a hydraulic cylinder. The hydraulic cylinder, with a set of operating linkages and a yoke/stock assembly, functions to transform hydraulic energy into linear motion and then into angular motion to operate the control surface. For a typical cylinder assembly see Figure 561-2-7. Specific design features, primary areas of hydraulic cylinder maintenance, and procedures to ensure proper reassembly are discussed herein. For applicable repair procedures to components of the hydraulic cylinders see Appendix A through Appendix E.

561-2.7.2 PISTON ROD PACKING AND PISTON SEALS. Where the piston rod passes through the cylinder head, V-type packing is generally used as a seal. On some later ships, two sets of packing are provided. This arrangement permits replacing the primary (outer) packing without having to isolate the hydraulic cylinder. During normal operation, the space between the two sets of packing is open to normal internal cylinder pressure. This situation results in a lack of differential pressure across the inner packing set and, therefore, negligible wear. Should primary packing leakage become intolerable, the normally pressurized space between the packing sets, now isolated from internal cylinder pressure, becomes depressurized and the inner packing begins to act as the primary seal. At this time, the outer packing can be replaced at first availability and then the cylinder restored to normal operation. The quad-ring is used as a piston seal in most installations, but in several early designs a leather U-cup seal was used for this purpose.

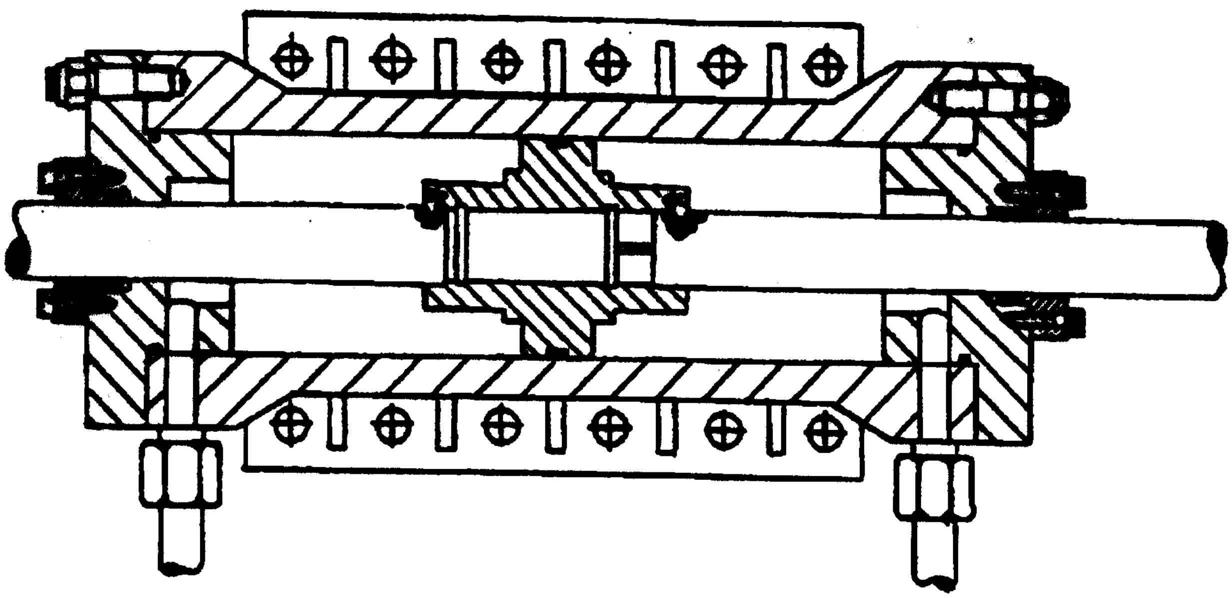


Figure 561-2-7. Typical Steering and Diving Hydraulic Cylinder

561-2.7.3 DYNAMIC SEAL LEAKAGE. Steering and diving system dynamic (reciprocating) seals are affected by extrusion, side loads, surface finish of the metal, concentricity of mating metal parts, seal hardness, squeeze, stroke speed, lack of lubrication, use of back-up rings, and compatibility of the seal material with system fluid. A newly installed seal will allow little or no leakage. However, with continued use, the factors listed above, in addition to system contamination, tend to reduce the effectiveness of the seal and increase the likelihood of leakage. Improper installation and damage during installation can be important factors in limiting seal life.

561-2.7.3.1 External Seals. Leakage from external seals (i.e., leakage that is external to the component such as that from the cylinder piston rod seal) is usually easily detected by visual observation. Generally, the most serious effect of this leakage is the oil accumulation and resultant housekeeping required. These seals are usually replaced before leakage becomes bad enough to affect operation of the cylinder or the ability to hold loads without drifting.

561-2.7.3.2 Internal Seals. Leakage from internal seals (i.e., leakage that is confined within the component such as within the seal on a cylinder piston) is difficult to determine and measure without conducting a test. Because the leakage is internal, it is often undetected until it becomes serious enough to significantly affect system operation. For example, on one nuclear submarine it was found that the stern planes were not functioning properly. Above 8 knots it became increasingly difficult to make the stern planes move in the rise direction. Continuous oil flow to the ram indicated that the seals on the piston of the stern diving cylinder had failed. At slow ship speeds, sufficient differential pressure could be generated across the piston to move the planes, but at higher ship speeds operation was very sluggish. This example indicates the importance of periodically testing the piston seals of steering and diving cylinders.

561-2.7.3.3 Criteria for External Seals. For external seals such as piston rod seals and similar applications, the leakage criteria in paragraphs 561-2.7.3.4 and 561-2.7.3.5 apply.

561-2.7.3.4 New Seals. For newly installed seals, a slight wetting of the tail rod is acceptable. Another acceptance criterion that may be used is the formation and dripping of not more than one drop of fluid every 25 cycles for each inch of rod diameter or fraction thereof. For example, a cylinder with a 2-1/4-inch tail rod would be allowed three drops of fluid per 25 cycles. A cycle for a cylinder is defined as operation from a fully retracted position to the fully extended position and back again to the fully retracted position.

561-2.7.3.5 Replacement Seals. In many cases, housekeeping problems resulting from leakage may be the primary factor in determining whether or not seal replacement is necessary. If, when the cylinder is not operating, leakage exceeds 4 milliliters per hour for each inch of seal diameter or fraction thereof, the seal should be replaced. If leakage occurs primarily during cycling of the cylinder, a leakage rate in excess of 1 milliliter per inch of rod (or seal) diameter or fraction thereof for every 10 cycles may be used as a criterion for replacement.

561-2.7.3.6 Criteria for Internal Seals. In the case of piston seals and similar internal applications, minor leakage is not detrimental. However, an increase in leakage is an early warning of seal deterioration. Leakage criteria selected should be those which will result in seal replacement before serious failure of the seal occurs.

561-2.7.3.7 Replacement Criteria. Because of cylinder design, measurement of piston seal leakage in most steering and diving system cylinders is limited to a static test. In general, internal piston seals should be replaced when leakage exceeds 5 milliliters per inch of seal diameter (or cylinder bore) per 5 minutes with the test pressure as close to operating pressure as practical.

561-2.7.3.8 Leakage After Seal Replacement. Following installation of new seals, there should be almost no leakage across the seal, particularly under static conditions. However, cylinders that are scored or otherwise damaged may leak slightly. The recommended maximum acceptable leakage is 1 milliliter per 10 minutes per inch of seal diameter.

561-2.7.3.9 Cylinder Seal Leakage Test. To determine hydraulic cylinder seal leakage rates, conduct the following static test annually (as a minimum). For valve numbers and relative direction of piston movement, see

Figure 561-2-8. For convenience in measuring piston seal leakage use ShipAlt SSN 2647D or MIL-V-24695 sampling components and guidance of **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** , section 556-8.12A

1. In local or emergency mode, slowly operate cylinder to the hard rise or hard left position until the hardstops are engaged.
2. After closing V-1, continue application of pressure through V-2.
3. Very carefully and slowly open V-3; if flow does not cease within a few seconds, a badly deteriorated piston seal is indicated.
4. If flow stops, or is reduced to a steady leakage, collect the leakage downstream of V-3 for a 5-minute period.
5. Observe tail rod seal for leakage under static and dynamic (operating) conditions.

NOTE

For the SSN 688 Class and SSBN 726 Class stern planes and rudder rams, the power transfer valve (PTV) is located between the system isolation valves (V-1 and V-2 of Figure 561-2-8) and the hydraulic cylinder. Due to this configuration, it is not possible to isolate the PTV leakage from the test. Although the above procedure is generally appropriate for shipboard testing, recognize that the test actually measures both ram and PTV leakage.

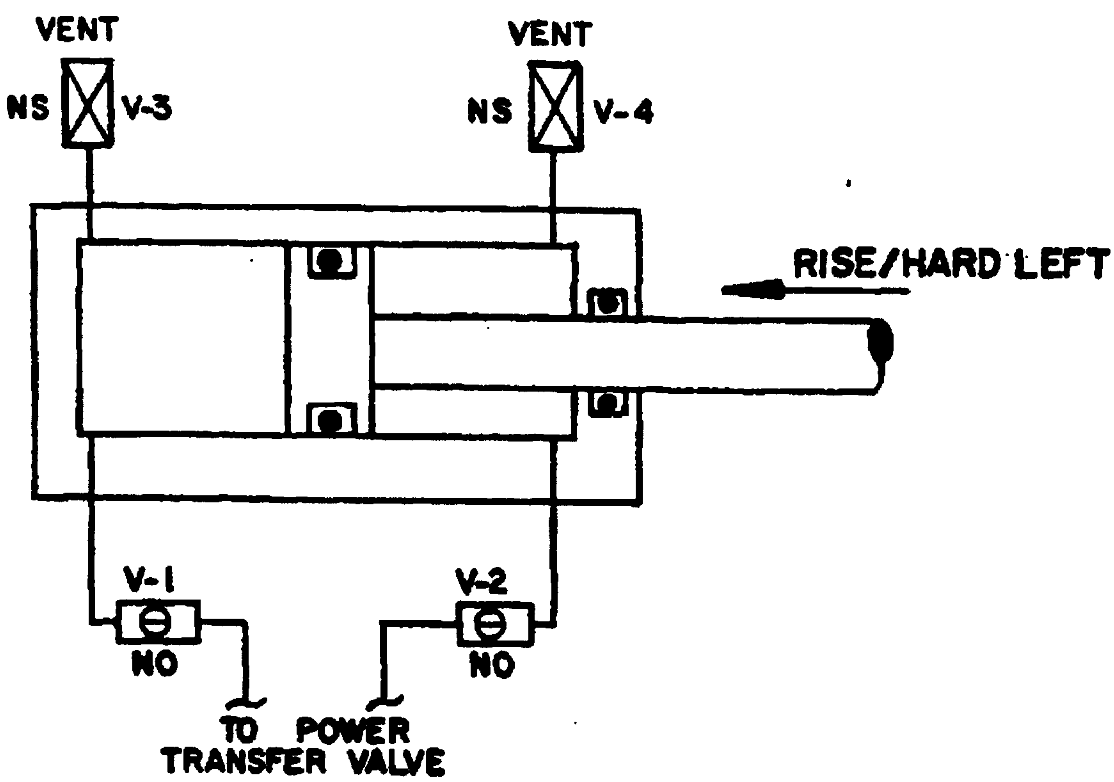


Figure 561-2-8. Cylinder Seal Leakage Test

561-2.7.3.10 Summary of Dynamic Seal Leakage Requirements. Acceptable dynamic seal leakage rates for external and internal dynamic seals are summarized in Table 561-2-2. All leakage rates are based on a fluid temperature of 37.8°C (100°F). If the fluid temperature is lower than 37.8°C (100°F) during performance of the tests, a leakage correction factor should be applied. For relative leakage rates based on fluid viscosity, see **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** . If excessive leakage is measured at temperatures over 37.8°C (100°F), a retest with cooler fluid is recommended in lieu of applying leakage correction factors.

561-2.7.4 REPLACEMENT OF PISTON ROD PACKING. Comprehensive guidance regarding installation of V-ring packing is provided in NSTM Chapter 078, Seals. The following is a general procedure for installation of V-ring packing in steering and diving hydraulic cylinders. It should be noted that some submarines have been provided with locking devices that, when installed between the guide cylinder and coupling and the hydraulic cylinder and coupling, lock the coupling in the center position to prevent movement of the operating gear.

1. Install the aforementioned locking device, if available.
2. Isolate the hydraulic cylinder from the hydraulic power source. Depressurize the cylinder using vent fittings on cylinder; drain the cylinder using drain fittings. Leave vent fittings in open position to preclude any pressure buildup in the cylinder as a result of component leakage. Unfasten packing gland and remove packing to be replaced.
3. Select packing components in accordance with size and material requirements specified on the applicable drawing.
4. Install V-ring packing in accordance with instructions in **NSTM Chapter 078, Seals** .
5. Reinstall the packing gland. Lubricate gland fasteners with molybdenum disulfide in accordance with MIL-M-7866, and tighten the fasteners to the appropriate torque values listed in Table 561-2-3. Ensure clearance exists between the ID of the gland and the OD of the shaft.
6. Observing standard shipboard precautions, slowly refill cylinder using low pressure fluid; vent off all air. Secure vents and bring cylinder slowly up to normal operating pressure, observing for leaks. Realign system for normal operations.

561-2.7.5 PISTON/CYLINDER HEAD CLEARANCE. Shipbuilding specifications require that the steering and diving hydraulic cylinders be designed so that the piston clears heads by at least 1/4 inch when the control surface is in the hardover (mechanical hardstop) positions. Most installations have been designed to provide 1/2 inch or more clearance. This additional clearance allows minor variation in the location of the cylinder, linkage manufacturing tolerances, and coupling shim thickness.

561-2.7.5.1 Recommended Verification Procedure. The following piston/cylinder head clearance verification procedure is the most accurate. Follow this procedure whenever possible:

1. With the cylinder fully assembled, but prior to installation in the ship, bottom the piston at both ends of the cylinder and measure and record dimensions A and B as shown in Figure 561-2-9.

NOTE

Measurements are to be made to the shoulder where the threads end and the polished portion of the rod begins rather than to the end of the piston rod. This is necessary to allow additional measurements when the coupling is installed. These dimensions should be measured to the nearest sixteenth of an inch and engraved on the end of the cylinder in decimals as shown in Figure 561-2-9.

Table 561-2-2 SUMMARY OF DYNAMIC SEAL ALLOWABLE LEAKAGE RATES NOTE 1

PART A - EXTERNAL SEALS (PISTON ROD)		
Maximum Leakage for New or Replacement Seals	**Recommended Maximum AccepLeakage Prior to Seal Replacement**	
	Dynamic Test	Static Test
1 drop/25 cycles for each inch of rod diameter or fraction thereof	1 mL per 10 cycles per inch of rod diameter or fraction thereof	4 mL/hr per inch of rod diameter or fraction thereof
PART B - INTERNAL SEALS (PISTON)		
Leakage Rate (Statis test only)	**Seal Condition**	**Corrective Action**
Less than 1 mL/10 minutes per inch of seal diameter (cylinder bore) or fraction thereof	New seal condition	None
Less than 1 mL/5 minutes per inch of seal diameter (cylinder bore) or fraction thereof	Satisfactory	None
1 mL to 5 mL per 5 minutes per inch of seal diameter (cylinder bore) or fraction thereof NOTE 2	Marginally satisfactory	Seal replacement should be scheduled for first convenient opportunity. If corrective action is not initiated within 3 months, the leakage test should be repeated.
More than 5 mL/5 minutes per inch of seal diameter (cylinder bore) or fraction thereof NOTE 2	Unsatisfactory	Replace piston seal.
Approximate Conversion Factors for Leakage Measurement		
1 teaspoonful	= 1/6 fluid ounce	= 5 mL
1 tablespoonful	= 1/2 fluid ounce 1 cubic inch 1 fluid ounce	= 15 mL = 16.4 mL = 30 mL
1 cup	= 8 fluid ounces	= 236 mL
1 quart	= 32 fluid ounces	= 0.95 liters
1 gallon	= 128 fluid ounces	= 3.78 liters

NOTE 1: All leakage rates are based on normal system operating pressures and a temperature of 37.8°C (100°F).

NOTE 2: Add 180 mL/5 minutes (SSN 688 CL) and 1800 mL/5 minutes (SSBN 726 CL) for rudder and stern planes hydraulic cylinders.

Table 561-2-3 PACKING GLAND FASTENER TORQUES (FT-LB)

Class Applicability	Stern Diving	Rudder	Fairwater/Bow
SSN 594 Class	364	364	N/A

Table 561-2-3 PACKING GLAND FASTENER TORQUES (FT-LB) -

Continued

Class Applicability	Stern Diving	Rudder	Fairwater/Bow
SSN 608 Class	364	364	364
SSBN 616/627 Class	364	364	364
SSN 637 Class	364	364	705
SSBN 640 Class	364	364	364
SSN 671	364	364	364
SSN 688 Class	573	623	573
SSBN 726 Class	34010	34010	66510

2. After installing the cylinder and coupling assembly, or any time thereafter when it is necessary to determine the clearance, measure dimensions As and Bs as shown in Figure 561-2-9.

NOTE

With the control surface in the two extreme limits of travel (mechanical hardstops) dimensions As and Bs are measured between the same two points used to determine dimensions A and B. The piston/cylinder head clearances are determined by subtraction as shown on Figure 561-2-9. The procedure described is not suitable for unmarked cylinders that are already installed in the ship, because it is not possible to bottom the piston against both ends of the cylinder after installation. An earlier procedure used by some activities required that the dimension of the piston rod extension at the mid-point position be etched on the end of the hydraulic cylinder, whereas the current procedure requires etching of the piston rod extension dimensions when the piston is at the bottomed positions.

561-2.7.5.2 Alternative Verification Procedure. The steering and diving system arrangement drawings for most ships give a dimension from the hydraulic cylinder to the center of the coupling that centers the piston in the cylinder. This is sometimes identified as the 0 or zero degrees condition. If necessary, use the following procedure as an alternative for verifying correct clearances.

1. With the coupling at the distance listed on the drawing for the 0 degree condition, measure the distance the piston is required to travel to move the piston rod into the hardstops in each direction.

2. Compare these travel distances with one-half the distance the cylinder travels (as determined from the cylinder drawing) to determine if the minimum 1/4-inch end clearance exists. For example:

   cylinder stroke (max) = 26.0 inches

   piston movement (forward) = 12.2 inches (forward)

   piston movement(aft) = 12.9 inches (aft)

   one-half cylinder stroke = 26.0/2 = 13.0 inches

   forward head/piston clearance = one-half cylinder stoke - pisto movement (forward)

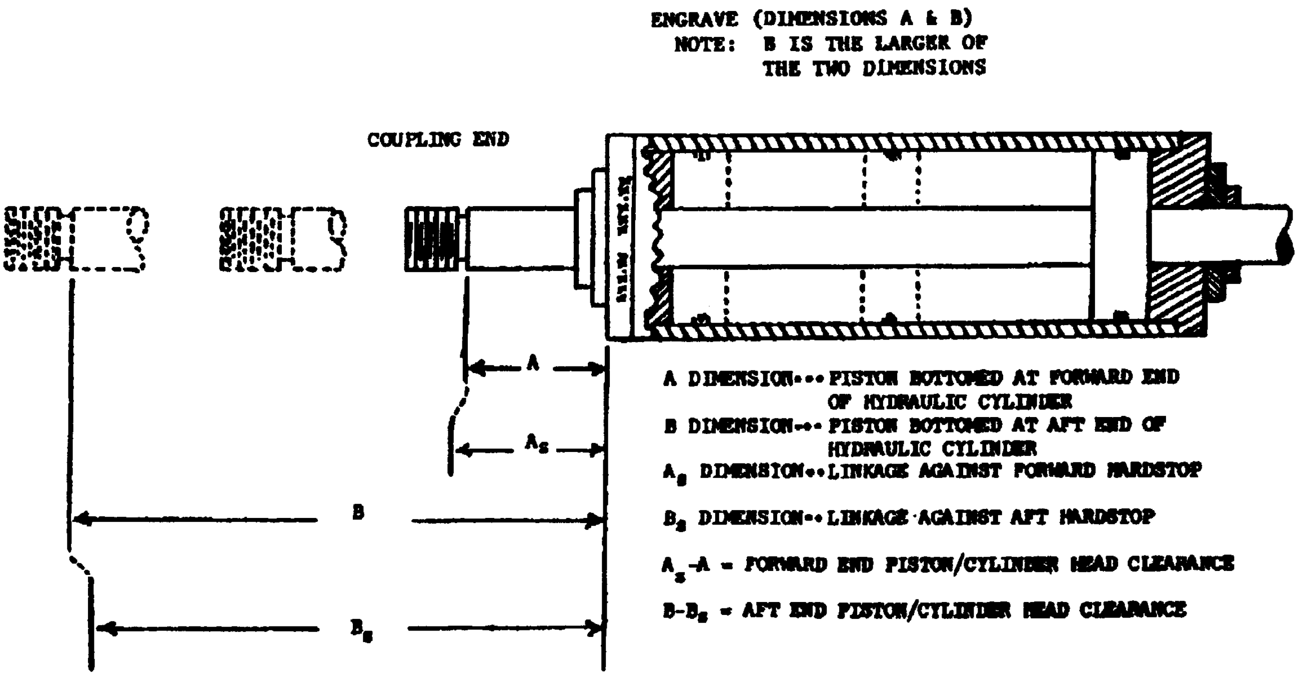


Figure 561-2-9. Piston/Head Clearance Determination

= 13.0 - 12.2 = 0.8

inch (satisfactory)

aft head/piston clearance = one-half cylinder

stroke - piston

movement (aft)

= 13.0 - 12.9 = 0.1

inch (unsatisfactory)

NOTE

The foregoing procedure will not determine end clearance for variations in piston rod length. Therefore, when a new piston rod is to be installed, verification must be made that the piston rod is the length required by the drawings. It should also be noted that the alternative procedure may be in error by as much as the shim thickness if a shim is installed in a coupling that was originally installed without a shim.

3. On the following installations, if no shim was originally installed, ensure that the minimum calculated clearance with a shim installed is 1/4-inch plus the shim thickness:

SSN 597 Fairwater Planes

SSN 585/588 Class Stern Planes and Rudder

SSN 598 Class Fairwater, Stern Planes, and Steering

SSN 608 Fairwater Planes

561-2.7.6 REMOVAL OF CYLINDER HEAD. If the foregoing checks reveal that a problem exists, investigate further as follows:

1. Move the control surface to the hardstop position and remove the cylinder head nearest to the piston

NOTE

Removal of the cylinder head requires prior depressurization, venting, draining, and isolation of the cylinder in accordance with standard shipboard procedures.

2. With the cylinder head removed, first measure the distance between the piston and the end of the cylinder and then measure the distance that the cylinder head extends into the cylinder. The difference between the two will equal the actual clearance.
3. Taking into account the clearance on this one end and the total distance the piston travels (hardstop to hardstop), calculate the clearance on the opposite end, using dimensions given on ship's drawings.
4. If it is concluded that a problem exists, inspect all mechanical linkage to ensure conformance to the drawing dimensions. If the cause of misalignment cannot be identified, request NAVSEA assistance or guidance to resolve the problem.

561-2.7.6.1 Torquing Of Cylinder Head Fasteners. Whenever the control surface operating cylinder heads are disturbed, it is important that the heads be reinstalled in the cylinder in a proper manner. Specifically, the fasteners that secure the heads to the cylinder body must be properly torqued. The fastener threads must be dry, clean, deburred, and lubricated with molybdenum disulfide in accordance with MIL-M-7866 (NSN 9150-00-943-6880; 203, tube). All nuts or capscrews must be evenly torqued to the appropriate values listed in Table 561-2-4.

Table 561-2-4 TORQUING OF CYLINDER HEAD FASTENERS

Class Applicability	Cylinder Head Fasteners Torque (Ft-lbs)		
	Stern Planes	**Rudder**	**Fairwater/ Bow Planes**
SSN 594 Class [Except 603, 604, & 612]	125-150	125-150	N/A
SSN 603, 604, & 612	150-275	200-225	100-125
SSN 608 Class	250-275	400-425	40-50
SSBN 616/627 Class	250-275	400-425	250-275
SSN 637 Class	175-200	300-325	350-375
SSN 671	200-225	325-350	140-150
SSN 640 Class	325-350	550-575	325-350
SSN 688 Class (688-750) (751-later) (SSN 718)	315-330 315-330 200-210	585-615 585-615 585-615	630-660 475-500 630-660
SSBN 726 Class	855-900	1780-1850	1780-1850
NOTE: For later ships, see the applicable NAVSEA steering or diving gear arrangement in ship and assembly drawing for torque values.			

561-2.7.6.2 Torquing of Hydraulic Cylinder Foundation Fasteners. Steering and diving hydraulic rams are secured to their foundations by various methods. These methods include: (1) fitted bolts (SSN 593, 637 and 688

Classes), (2) combinations of fitted and tapered bolts (SSBN 616, 627 and 640 Classes), (3) tension bolts (SSN 688 and SSBN 726 Classes fairwater planes ram), and (4) combinations of bolts and tapered stop blocks (SSBN 726 Class steering and stern diving rams). The intent of these methods is to secure the cylinder to its foundation and reduce axial movement. All of these designs rely upon fasteners which are preloaded to a specified torque. Table 561-2-5 gives torque values which provide the optimum preload. In some cases, the values given exceed the torque values listed in the design drawings. Lubricate threads and surface under nut with molybdenum disulfide. Use of self locking nut is permitted to avoid use of cotter pin or key. Add run-down torque of self-locking nut to tabulated values. Use hydraulic torque wrench whenever it is available or practical.

561-2.7.6.3 Inspection of Ram Axial Movement. The following provides information and guidance for inspection of hydraulic ram axial movement:

1. Inspections of axial movement of the ram should be kept to a minimum since this test applies forces to the steering/stern diving linkage which exceed the maximum hydrodynamic loads that are applied in service. Inspections should be made after overhaul or refurbishment, to verify work, and whenever URO MRC 015 is conducted to check for material degradation and wear. Inspections should be scheduled in conjunction with any tests involving application of ram load to the steering or diving gear, such as: dockside testing of the coupling, measurement of dogbone freeplay, verification of coupling tightness, and measuring tiller contact area.

Table 561-2-5 OF TORQUE VALUES AND SELF-LOCKING NUT PART NUMBERS - For Ram Foundation Fasteners

Ship/Class	Control Surface	Dwg. No.	Pc. No.	Torque [Ft-Lbs]	Self-Locking Nut Part No.
SSN 594CL	Steering Stern Fairwater	1863775-D 1863775-D 1862352	2 2 22	820-870 820-870 200-220	MS17829-24C MS17829-24C MS17829-14C
SSBN 616CL 627CL	Steering Stern Fairwater	1862352-C 2006785-F 2007152-J	3 3 6	1180-1250 890-940 950-1000	Note 1 MS17829-22C MS17829-22C
SSN 637CL	Steering Stern Fairwater	2140776 2140779 2141299	15/22 16/23 14/20 15/19 25	420-440 1470-1550 1140-1200 390-420 1280-1350	MS17829-16C MS17829-24C MS17829-22C MS17829-16C MS17829-24C
SSBN 640, 643, 645	Steering	2116253-F	2 4 16 22 25 27	340-360 70-80 1800-1900 290-310 430-460 1140-1200	MS17829-16C MS17829-14C Note 1 MS17829-16C Note 1 Note 1
SSBN 641, 642, 644, 654, 655, 656, 657, 659	Steering	2437921-A	4 16	630-660 2660-2800	Note 1 Note 1
SSBN 640CL	Steering Fairwater	2116257-D 2116257-E 2116866-R	2 14 18 7 17	230-240 430-450 1560-1650 250-270 1280-1350	MS17829-14C MS17829-16C Note 1 MS17829-14C MS17829-24C

Table 561-2-5 OF TORQUE VALUES AND SELF-LOCKING NUT PART NUMBERS - For Ram Foundation Fasteners - Continued

Ship/Class	Control Surface	Dwg. No.	Pc. No.	Torque [Ft-Lbs]	Self-Locking Nut Part No.
SSN 688CL	Steering	4457086-A	33	1140-1200	MS17828-24C
	Stern	4457083-V	36	450-480	MS17828-18C
	(688-750)	5529815-B	16	1180-1250	MS17829-24C
	(718)	4457083-V	28	610-640	MS17828-20C
	(751-LTR)	4457128-S	16	1180-1250	MS17829-24C
	Fairwater	5794753-J	23	720-760	MS17828-22C
	Bow Planes		37	2300-2400	MS17829-28C
SSN 726CL	Steering	4640783-F	5	1900-2000	Note 2
	Stern	4640786-F	6	1255-1300	Note 2
	Fairwater	4645234-K	5	1900-2000	Note 2
			6	1255-1300	Note 2
			26	2370-2500	MS17829-28C

Note [1] Not available in required size.

Note [2] Not applicable; bolt-tapped hole assembly.

2. Inspection of ram axial movement is made by mounting of dial indicator to the ram foundation and noting the movement of the ram after maximum hydraulic differential pressure is applied. Erroneous data can be obtained if the following steps are not carefully followed:
   a. Mount the indicator base as close as possible to the pointer. Locate the pointer shaft perpendicular to the vertical surface of the ram feet or pads and as close as possible to the joint between the ram feet and the foundation and the ram axial center line. Figure 561-2-10 shows the correct orientation of the dial indicator for a steering ram. If the indicator is improperly mounted or skewed to the horizontal, then inaccurate readings will result. Make appropriate adjustments in this procedure for the SSN 688 Class fairwater planes hydraulic cylinder, since it is vertically mounted at the lower cylinder head.
   b. Using the local manual or emergency control mode, move to one of the hard stop positions, applying maximum hydraulic cylinder differential pressure with the tiller against the hard stop. Control the rate of the tiller's movement into the hard stop to avoid damaging any equipment.
   c. Relax the applied ram pressure to the foundation by moving the tiller a small distance (1/8 inch maximum) away from the hard stop. Do not relax the ram pressure for the SSN 688 class fairwater planes hydraulic cylinder.
   d. Zero the indicator.
   e. Move the planes in the opposite direction and repeat steps b. and c. above. Read the indicator to obtain the total axial movement of the ram. With the exception noted above for SSN 688 class fairwater planes, it is important that the dial indicator is read after the ram pressure is relaxed, otherwise the elastic spring or deflection of the foundation fasteners and equipment will influence the data. The purpose of the test is to measure only the actual ram shift on its foundation, due to distorted bolts or bolt holes.

3. Inspection criteria for maximum allowable axial movement of the hydraulic ram are given by paragraph 561-2.7.6.4 below. Movement in excess of these amounts indicates the onset of rapidly increasing wear, insufficient torque or both. If proper torquing does not reduce axial movement to the maximum allowable value then restore cylinder mounting fasteners and bolt holes to drawing requirements.

4. Documentation of ram axial movement shall be made using Maintenance Requirement Cards (MRC) for SRA/ERP availabilities and Technical Repair Standards (TRS) for regular overhauls or depot availabilities.

5. It is important that the foundation fasteners are properly torqued to maintain the maximum preload of the fasteners and clamping force of the foundation to the cylinder. See paragraph 561-2.7.6.2. If the inspection of relative motion shows values in excess of the maximum allowed of Table 561-2-6 then the torque of the fasteners should be checked and the inspection redone. This may avoid the need for unnecessary repair action.

561-2.7.6.4 Hydraulic Ram Movement. Relative motion between a hydraulic cylinder and its foundation may occur due to one or more of the following reasons:

a. Insufficient fastener preload.

b. Elastic bending and shear deflection of the fitted bolts and/or tapered pins in way of shim pads.

561-2.7.6.5 Acceptable Ram Movement. Table 561-2-6 lists the amount of relative motion in the direction of ram travel that is acceptable on new installations and on existing installations that have been refurbished to design dimensions and tolerances. It also tabulates the maximum allowable cylinder to foundation relative movement for in-service submarines.

561-2.7.7 CYLINDER PISTON LOCKING DOWEL INSTALLATION. Except for the addition of an alinement shim, the cylinder piston configuration used in steering and stern diving hydraulic cylinders without tailshafts for SSN 637 class and other ships with similar design cylinders is shown in Figure 561-2-11(a). In this configuration, the piston and aft dashpot dasher are secured by the forward dasher, which is threaded onto the piston rod at assembly. The forward dasher is locked onto the piston rod by an axial locking dowel at the interface of the dasher and the piston rod ends. The locking dowel is then held in place by a retaining plate secured to the end of the piston rod.

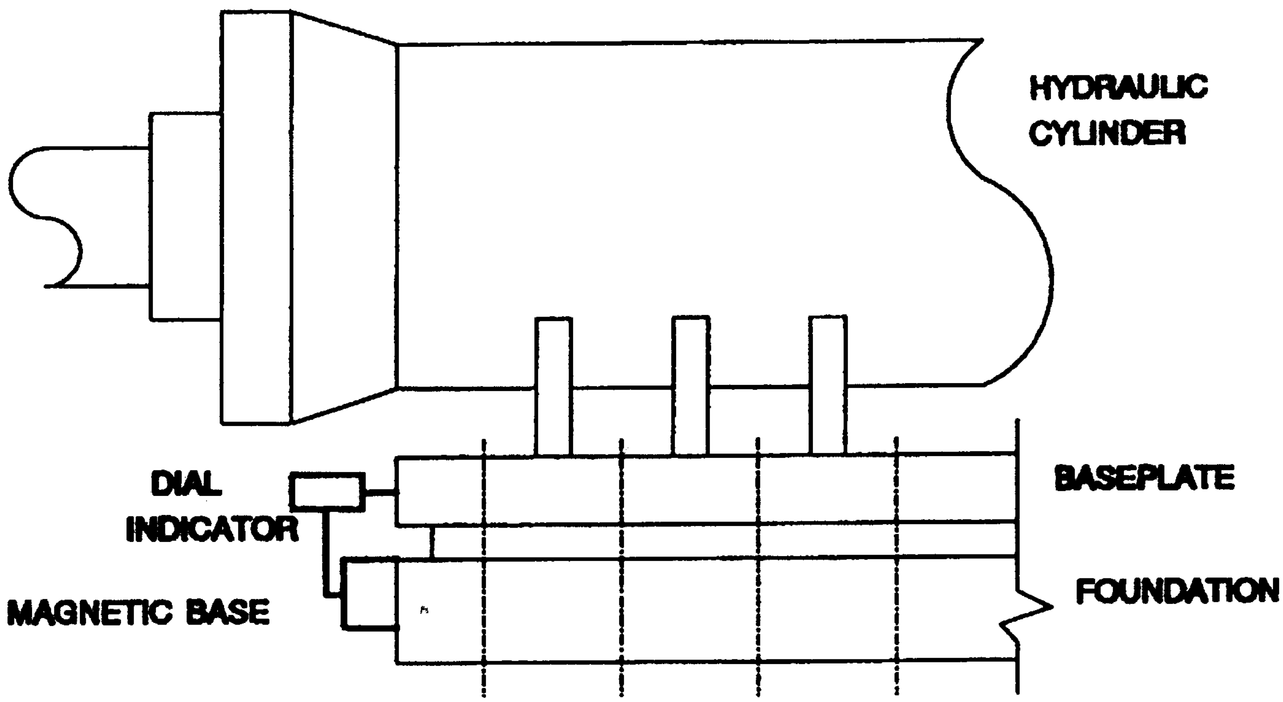


Figure 561-2-10. Hydraulic Ran Axial Movement Inspection

Table 561-2-6 HYDRAULIC RAM MOVEMENT

CLASS	MAXIMUM ALLOWED MOVEMENT (IN)	
	DESIGN	IN-SERVICE
Pre-688 688 Note 1 726	0.005 0.005 Note 2	0.020 0.020 Note 2

Note 1 Fairwater = 0.002″ for both design and in-service.

Note 2 Measurements are not required due to the design of mountings and hard stop arrangement.

561-2.7.7.1 Locking Dowel Misalinement. After rework, the locking dowel hole in the dasher sometimes goes past the portion of the locking dowel hole in the piston rod when the dasher is torqued onto the piston rod. This misalinement can be the result of previous improper assembly or can be caused by machining the faces of the aft dasher, piston, or forward dasher to obtain the surface finish identified in Technical Repair Standards (TRSs). To prevent misalinement, no machining should be done on the faces of the piston or dashers unless required to ensure proper seating of the components or to eliminate surface imperfections that could affect cylinder operation. If misalinement occurs, alinement shall be corrected by shimming or by relocating the piston locking dowel as described in paragraphs 561-2.7.7.2 through 561-2.7.7.3.

561-2.7.7.2 Shimming to Obtain Locking Dowel Alinement. The more preferable method for correcting the alinement of the holes for the locking dowel is through the use of a shim. Since the forward dasher has advanced too far under torque, the installation of a shim of proper thickness between the piston and forward dasher will realine the dowel holes in the rod and forward dasher. See Figure 561-2-11 a.

561-2.7.7.2.1 The thickness of the shim shall be as required to produce proper dowel hole alinement. The proper thickness can be determined by torquing the dasher against feeler gages or laminated shim stock inserted between the dasher and the piston. The shim shall be made from nickel-copper sheet, QQ-N-281 Class A, or Corrosion-Resistant Steel (CRES) sheet, Condition A, Class 304, 304L, 316 or 316L per QQ-S-766. Shim material of the required thickness is rarely available from the supply system and laminated shim stock is not to be used for permanent installation. The thicker standard sheets listed in Table 561-2-7 can be used, however, by skim-cutting the face of the forward dasher. The face of the dasher to be cut should be the one next to the piston.

561-2.7.7.2.2 The inside diameter of the shim shall be .003/.005 inch larger than the diameter of the piston rod land on which the shim is to be installed. The outside diameter of the shim shall be the same as the outside diameter of the forward dasher. After the shim is inserted, the dasher shall be torqued as indicated on the applicable drawing. Shims in excess of the sheet thicknesses as listed in Table 561-2-7 should not be used.

561-2.7.7.3 Piston Locking Dowel Relocation. A less preferable method for correcting misalinement of the dowel locking hole is shown in Figure 561-2-11. In this method, a new locking dowel hole is drilled at the dasher drive hexagon point 120 degrees from the existing dowel hole after the dasher has been torqued onto the piston rod. The dowel hole may be redrilled (as shown in Figure 561-2-11 b.) only twice. Subsequent misalinement will require correction by the method given in paragraph 561-2.7.7.2 or by replacement of the piston rod. The dowel hole shall be drilled in accordance with requirements of the applicable drawing.

561-2.7.8 STERN DIVING GEAR DIVE LIMIT STOP MECHANISMS. The stern diving rams of SSN585/SSN588 class, SSN688 class, and SSBN726 class are equipped with hydraulically actuated dive stop mechanisms which prevent plane movement beyond a preset angle. The SSN585/SSN588 stop is a jaw type device. The stop mechanisms on SSN688 and SSBN726 consist of a cross-shaped stop keyed onto the ram tailrod, and a rotating striker plate, with a cross-shaped opening, which is mounted to a housing on the forward end of the ram.

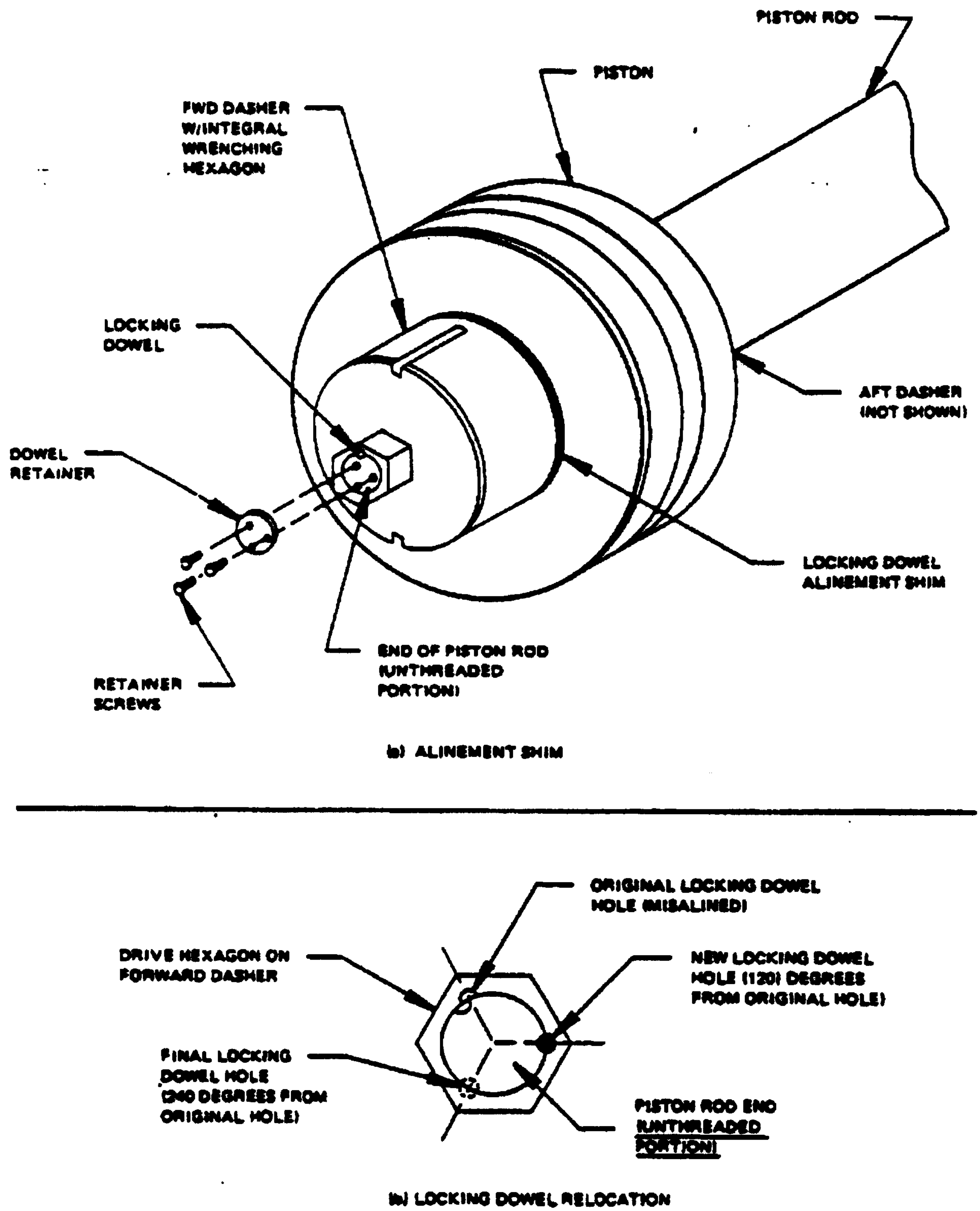


Figure 561-2-11. Hydraulic Cylinder Piston Alinement and Locking Dowel Relocation

Table 561-2-7 SHEET STOCK MATERIAL FOR CYLINDER PISTON ALINEMENT SHIMS

Thickness	Nickel Copper QQ-N-281 Class A	CRES Class 304, Condition A
.019	9535-00-767-2064	9515-00-204-4536
.025	----------------	9515-00-204-4558
.031	9535-00-232-2307	9515-00-204-4556
.038	9535-00-234-2161	9515-00-204-4533
.050	9535-00-232-2308	9515-00-204-4528
.063	9535-00-234-2166	9515-00-204-4529

561-2.7.8.1 SSN585/SSN588 Class Ram Stop Operation. During dive stop engagement the two halves of the jaw type stop mechanism are closed around the ram tailrod by a single hydraulic cylinder acting through a common toggle linkage. A collar, mounted on the ram tailrod, comes to bear against the end of the closed jaws, thus limiting travel of the planes in the dive direction. When the stop is disengaged, the jaws swing clear of the tailrod and full ram travel can be achieved. The planes cannot be trapped by engaging the stop mechanism at dive angles greater than the preset value since the jaws of the stop cannot be closed sufficiently to capture the tailrod collar.

561-2.7.8.2 SSN688 Class and SSBN726 Class Ram Stop Operation. During dive stop engagement the striker plate is rotated 45 degrees to interfere with tailrod motion. During dive stop disengagement the striker plate rotates to a position which allows passage of the tailrod stop with a clearance of 1/4 inch on each side of the four stop arms. Having passed into the striker plate, the tailrod stop prevents the striker plate from rotating into its closed position, which prevents the planes from being trapped at a dive angle greater than the preset limit value.

561-2.7.8.3 Correction of SSN688 Class Tailrod Stop Misalinement. A significant difference exists between the stop assemblies on SSN688 class and SSBN726 class. The SSBN726 class tailrod stop is captured throughout its travel by a guide mounted on the striker plate housing. If the striker plate on a SSBN726 class is properly oriented when disengaged, the tailrod stop will be guided into the striker plate with proper clearances. The SSN688 class stop assembly has no such guide prior to entry into the striker plate and relies on the axial key in the tailrod to establish its orientation. If sufficient misalinement exists between a SSN688 class tailrod stop and its disengaged striker plate, interference with tailrod motion and damage to the stop or striker plate can result when the stop enters the striker plate. If a misalinement of the stop to the striker plate is noted which produces a clearance of less than 3/16 inch on either side of any of the four stop arms, the following corrective actions shall be taken:

1. Verify that the striker plate is properly oriented in the disengaged position. This may be done by verifying that the cross-shaped opening in the striker plate is rotated to aline with the cross-shaped opening in the fixed housing to which it is secured. If the striker plate orientation is incorrect, investigate and correct the cause of this misalinement.
2. If the striker plate is in proper orientation to the fixed housing but the tailrod stop is out of acceptable orientation to the striker plate, the axial key which holds the stop on the tailrod must be refitted or reworked in accordance with actions 3 through 11.
3. Remove the stop from the tailrod and inspect the key and mating key slots for proper fit. Refit the key if required.
4. If the key is found to have proper fit but is producing an improperly oriented stop, manufacture and install a stepped key in accordance with actions 5 through 10.

5. Reinstall the stop on the tailrod without the axial key. Engagement of the stop on the tailrod should leave a portion of the key slot in the tailrod visible.
6. Aline the stop to produce 1/4 inch clearance between the sides of the striker plate aperture and each side of the four stop arms. Lock the stop in place using the two set screws in the stop.
7. Scribe the circumferential location of the tailrod key slot on the hub of the stop to establish the offset between the stop and tailrod key slots (Figure 561-2-12, Detail A).
8. Using the offset obtained in subparagraph 7 determine the width of new key slot required in the tailrod stop hub by the following formula: W (slot width) = 1/4 + (2 x offset dimension) + .010 inch The depth of the new key slot shall be 9/64 inch (Figure 561-2-12, Detail B).
9. Scribe the centerline of the new key slot on the hub of the tailrod stop at an offset from the existing key slot centerline equal to the offset obtained in actions 7 and machine a new key slot to the width and depth in action 8.
10. Manufacture a new stepped key in accordance with Figure 561-2-12, Detail C. The key material shall be Nickel Copper, QQ-N-281, Class A Cold Drawn and Stress relieved.
11. Reassemble the stop on the tailrod using the stepped key and verify proper stop to striker plate alinement.

561-2.7.9 SSN637 CLASS FAIRWATER DIVING GEAR DIVE STOP PLATE INSTALLATION. Although not in the class design, the fairwater diving gear hydraulic ram cylinders of some SSN637 class submarines have a special stop plate mounted on top of the packing gland of the main cylinder upper head. The purpose of this plate is to provide a stop for the under-ice lock ring to prevent a fairwater plane dive jam by limiting the travel in emergency mode to approximately 20-1/2 degrees. The configuration of these stop plates are similar to that shown on drawing number SSN637-518-2663781 Revision D, Detail 8-A in zone 8-D. When encountered, this stop feature shall be retained.

561-2.8 STEERING AND DIVING MECHANICAL GEAR

561-2.8.1 TYPICAL STEERING AND DIVING GEAR ARRANGEMENTS. For each control surface, the power developed by the hydraulic cylinder is transmitted through connecting rods to a tiller that, in turn, causes the control surface stock to rotate. A typical steering and stern diving gear arrangement is shown in Figure 561-2-13. On most submarines, the forward diving planes are located in the fairwater (sail) and are known as fairwater planes. If the planes are located on the hull forward of the fairwater, they are called bow planes. A typical fairwater diving plane arrangement is shown in Figure 561-2-14. Some SS type submarines such as SS 574 have a special stern plane mechanical arrangement. The stern plane stock and supporting bearings are arranged in an outboard skeg appendage just forward of the rudder and below the hull. The planes are all movable and cantilevered about a bearing support located at the skeg. The tiller assembly is located within the skeg and is linked by means of connecting rods to the actuating cylinders that penetrate the pressure hull. Fairwater, bow, and stern plane stocks are supported by plain-sleeved bearings or spherical-sleeved bearings. The rudder stocks are retained by spherical-sleeved bearings, with the weight of the rudder being supported by thrust washers (carrier bearings).

561-2.8.2 STEERING AND DIVING LINKAGE COUPLING. In most installations, the steering and diving hydraulic cylinder piston rod is connected to the guide cylinder (or crosshead) connecting rod by an internally threaded coupling secured in position by two locking bolts as shown in Figure 561-2-15. Also, in most assemblies, a shim is installed between the two rod ends. The purpose of the shim is to provide a variable dimension which aids in the process of alining existing locking bolt holes in the coupling and the rods. Discussions herein are applicable to the following submarines having couplings similar to that shown in Figure 561-2-15:

All SSBNs SSN 637 Class

SSN 585/588 Class SSN 671

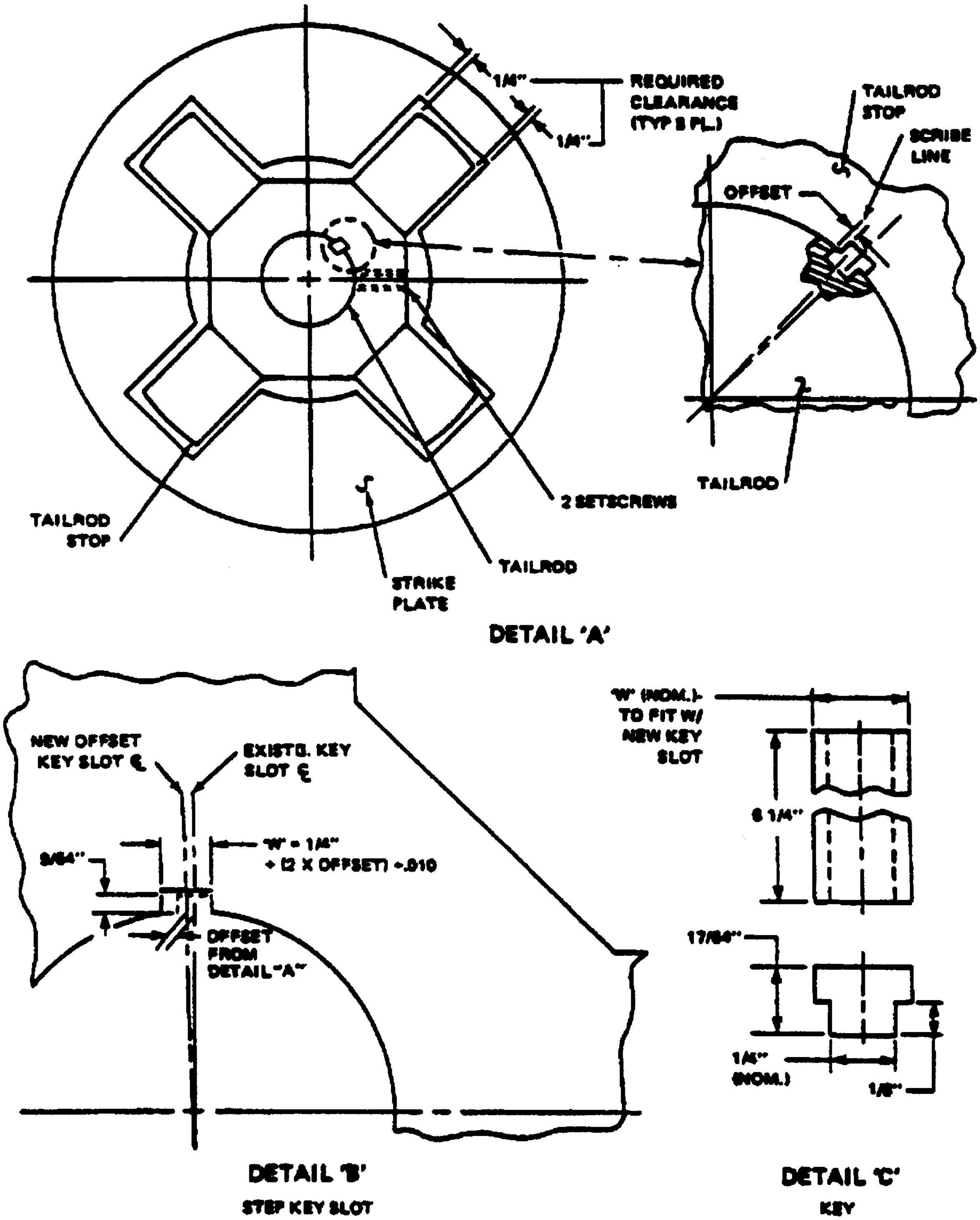


Figure 561-2-12. Step Key Slot

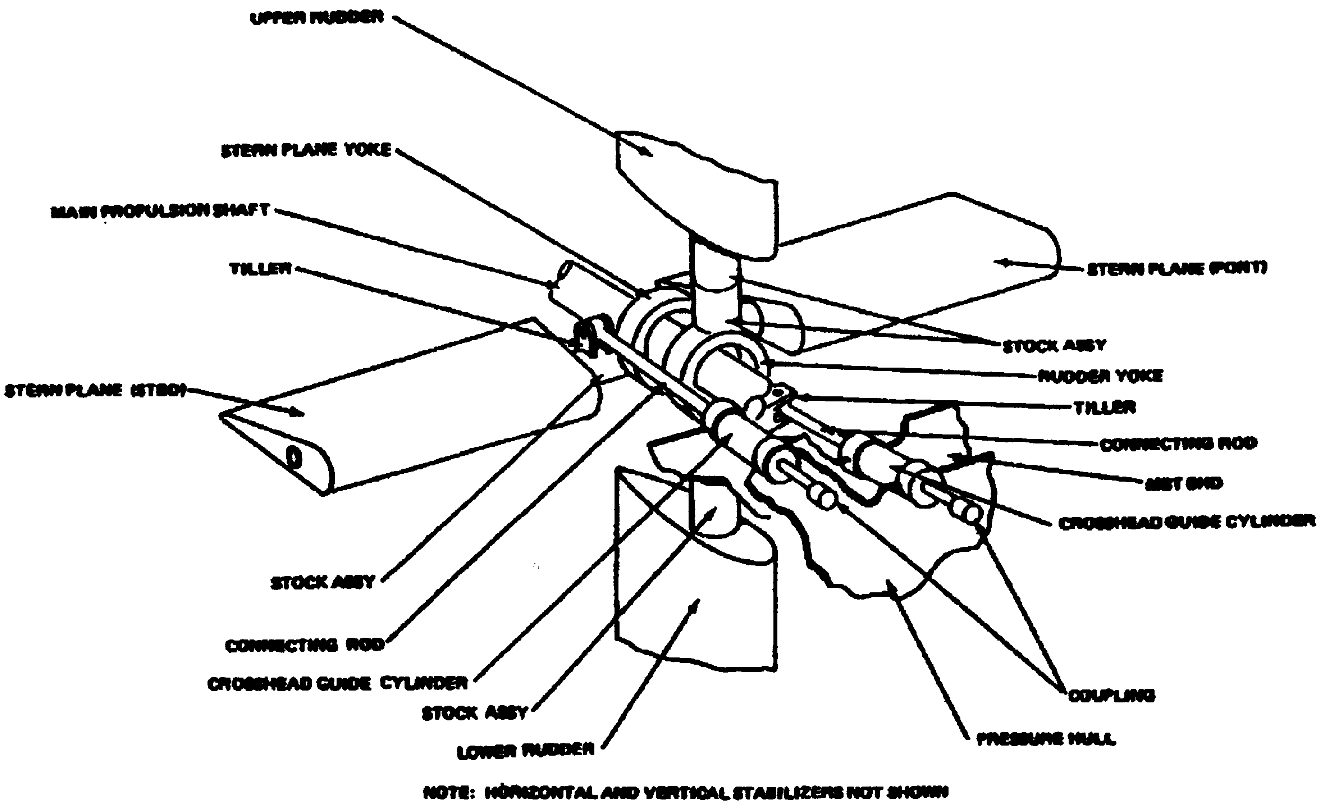


Figure 561-2-13. General Arrangement of Steering and Stern Diving Gear

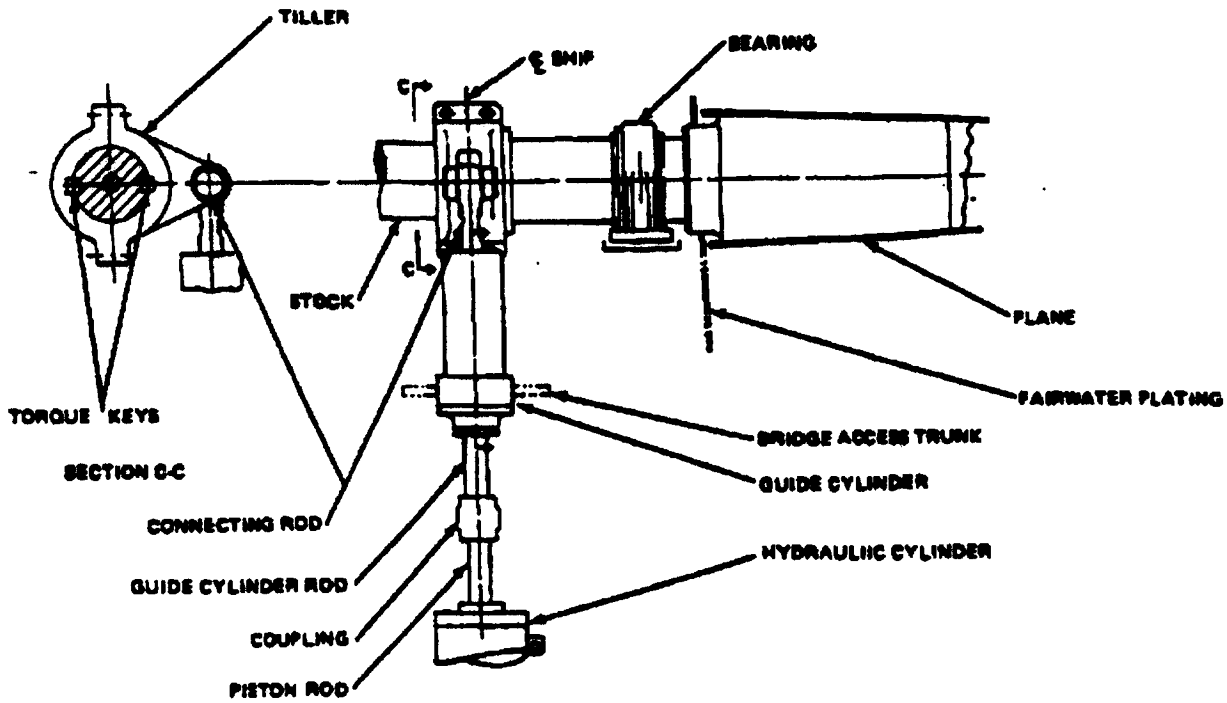


Figure 561-2-14. Fairwater Diving Arrangement

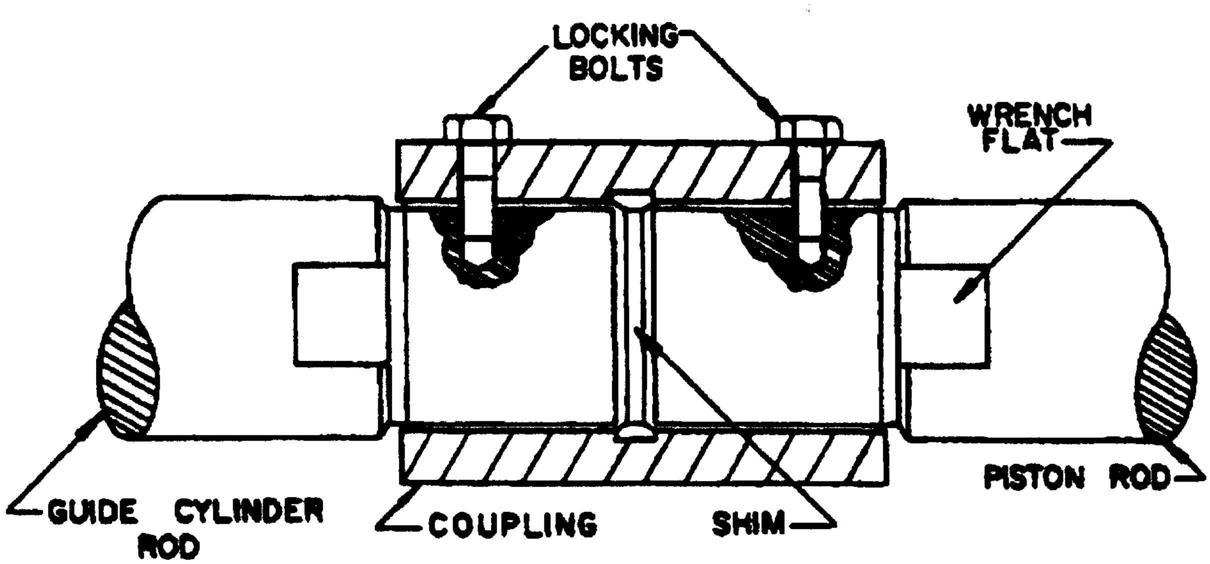


Figure 561-2-15. Coupling Arrangement

SSN 594 Class SSN 685

SSN 597 SSN 688 Class

SSN 598 Class

SSN 608 Class

561-2.8.2.1 Coupling Installation Requirements. This procedure is followed whenever a coupling assembly is installed or reassembled. It varies from the procedures given by steering and diving assembly drawings. The steps are listed as follows:

1. Verify coupling alinement and realine as necessary. (See paragraph 561-2.8.4.2).
2. Torque coupling to the torque value given by Table 561-2-8. Use a thread lubricant (molybdenum disulfide) to prevent galling. Thread coupling on one rod one complete thread before engaging the other rod to avoid cross-threading. Hold the rods fixed and rotate the coupling to draw both rods into the coupling simultaneously. This will prevent damage to any thread locking devices in the ram or guide cylinder piston. (SSBN 726 class ships have a unique coupling locking bolt configuration, with an adjustable alinement plug at the inboard end of the coupling but no adjustment at the outboard end of the coupling. When torquing an installation containing a through hull rod already having a locking bolt hole, the advance of the coupling must stop when the bolt holes at the outboard end are in alinement; then the locking bolt must be installed. After this bolt is installed, hold the coupling fixed and rotate the piston rod until specified torque is achieved.)
3. Exercise the coupling by applying the maximum force of the hydraulic cylinder to the coupling assembly. Move the tiller into contact with each hard stop at least three times. After contacting the hard stop, maintain hydraulic cylinder load against the hard stop for a brief period of time (5-10 sec). Use available 3000 psi hydraulic power source.

CAUTION

Control the rate of the tiller's movement into the hard stops to avoid damaging any equipment.

NOTE

In some cases, these values exceed ship's drawing requirements.

4. Verify coupling has not loosened after step 3 by attempting to retorque coupling to required torque value.
5. If coupling rotates during step 4, repeat steps 3 and 4 until step 4 can be performed without a rotation of the coupling.

Table 561-2-8 TABLE OF TORQUE VALUES FOR COUPLING

Ship Applicability	**Coupling Torque Value in Ft-Lb (-0 ft-lb) (+200 ft-lb)**		
	Stern Planes	**Rudder**	**Fairwater/ Bow Planes**
SSBN 616/627CL	2000	2000	2000
SSBN 640 Class	2000	2000	2000
SSN 688 Class	2000	2000	2000
SSBN 726 Class	3000	3000	3000
Other SSN's	1400	1400	1400
Other Than Above	Drawing	Drawing	Drawing

6. For a new coupling assembly (consisting of either a new coupling or rods or both), drill holes in new coupling/rods as necessary and install locking bolts. For a used coupling assembly, resize shim and assemble coupling to maintain required torque value. For SSBN 726 Class ships with locking bolt plugs, manufacture and install new plugs to aline locking bolts.

561-2.8.2.2 Coupling Locking Bolts. Once installed, the locking bolts should be lockwired in accordance with MS-33540 with lockwire conforming to MS-20995. Lockwire material can be either monel or CRES

CAUTION

More than one tapped hole in the rod is prohibited without NAVSEA approval as this could significantly reduce the strength of the rod. Proper coupling assembly as discussed herein is mandatory.

561-2.8.2.3 Coupling Disassembly. When the coupling must be removed from the linkage in order to perform maintenance or repair of the hydraulic cylinder or mechanical linkage, proceed as follows:

1. Prior to starting disassembly, position the affected control surface to the neutral (zero degree) angle position and, if possible, block the control surface in that position to prevent further movement. When the diving planes cannot be blocked in this manner, position these planes in the hard rise (fairwater) or hard dive (stern diving) position (mechanical hardstop) by using either the local or emergency control mode. This will prevent the diving planes from uncontrolled movement when the coupling is disengaged.

2. Secure all hydraulic power to the operating cylinder by shutting the isolation valves to the cylinder.

3. Vent and drain both ends of the hydraulic cylinder. Disconnect all linkage, such as feedback transmitter linkage, from the coupling.

4. Remove the two locking bolts from the coupling.

5. Prior to further disassembly, scribe reference lines (axially in line with the tapped holes for the locking bolts as shown in Figure 561-2-16) on each rod and the vertical faces (ends) of the coupling. Sealing wax may be used as a base on which to scribe the marks. The tapped holes on the rod ends will be obscured from view within the coupling as they near their final positions during reassembly and the reference lines will be of considerable value in maintaining the orientation of the holes.

6. Prior to further disassembly, determine the proper shim thickness (paragraph 561-2.8.2.6) and make this information available for use during reassembly.

7. Mark the hydraulic cylinder end of the coupling so it can be easily identified for certain shim fitting procedures and reassembly.

WARNING

Upon coupling removal, all personnel shall stay clear of the space vacated by the coupling. Wave action and currents can exert forces sufficient to move the control surfaces and such movement can result in the guide cylinder rod impacting against the piston rod. Forces are severe enough to cause loss of life or dismemberment. The general area shall be posted as a danger area.

CAUTION

Cylinder piston rod rotation during maintenance of couplings may subject equipment to undue strain and shall be avoided unless otherwise specified.

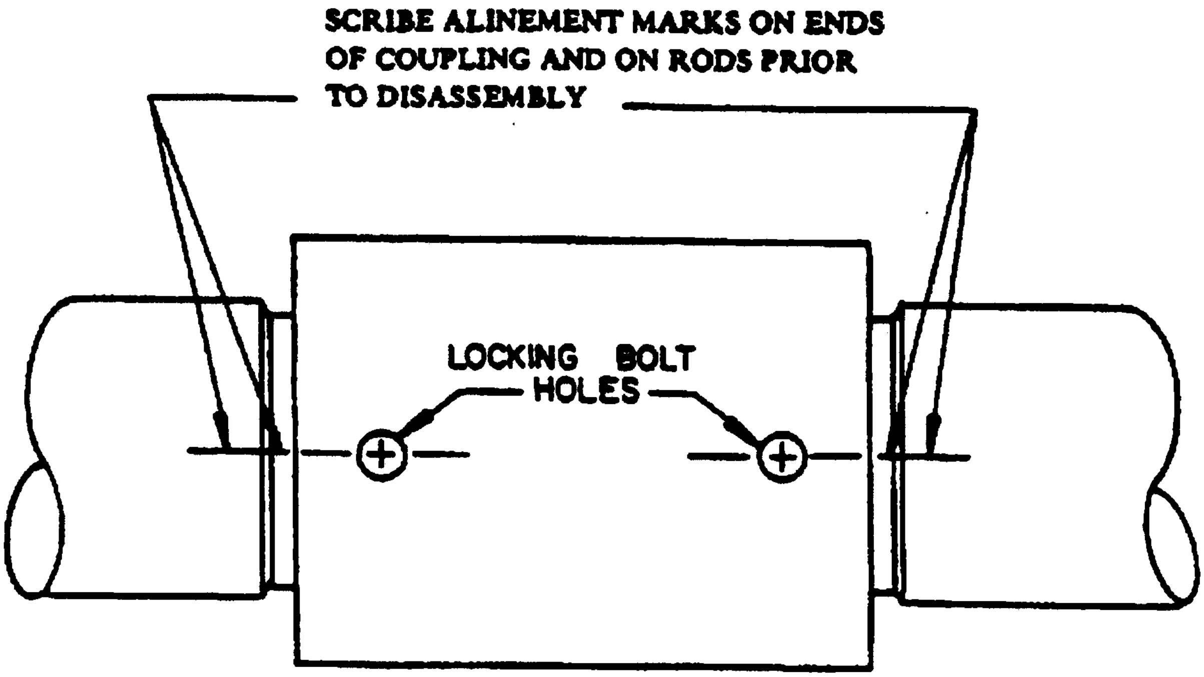


Figure 561-2-16. Location of Alinement Marks

8. Remove the coupling from the linkage.

561-2.8.2.4 Rod Rotation. When installing, disassembling, or reassembling coupling, do not allow the guide cylinder rod to rotate as this places undue stress on the yoke pin and the crosshead pin.

561-2.8.2.4.1 When installing, disassembling, or reassembling coupling, do not allow the hydraulic cylinder piston rod to rotate as this may place undue stress on piston to piston rod fastening screws.

561-2.8.2.5 Shim Fitting. Shim fitting becomes necessary when it is impossible to aline the coupling clearance holes and the tapped holes in the piston and guide cylinder rods following torquing of the coupling. In this case, alinement is achieved by changing the thickness of the shim. Under no circumstances should additional holes be added to either the coupling or the rods. If great difficulty is encountered in obtaining the shim thickness necessary in order to aline the holes, the coupling hole may be slightly elongated in the direction of the coupling axis, to allow accommodation of the bolt. An elongation of up to 1/8 inch is permissible if the elongation blends smoothly with the original hole and has no corner ridges or cusps. Shims should be machined from the same material as the piston rods. The diameter of the shim should be 1/8 inch less than the ID of the coupling.

561-2.8.2.6 Determining the Thickness of a Replacement Shim. If a coupling assembly, complete with an existing shim and locking bolts, requires reshimming, the thickness of the new shim will be equal to the thickness of the old shim plus the required increase in thickness as determined by the following procedure:

1. With the original shim still in the coupling, aline the tapped holes in the rods with the clearance holes in the coupling (the assembled condition with the locking bolts removed).
2. Attach a dial indicator to one of the rods with the indicator plunger in contact with the end of the coupling.
3. Torque the coupling to a value per Table 561-2-8, making certain that neither rod rotates.
4. Double the movement measured on the dial indicator (because both rods move into the coupling) and add this value to the measured thickness of the existing shim to calculate the thickness required for the new shim.

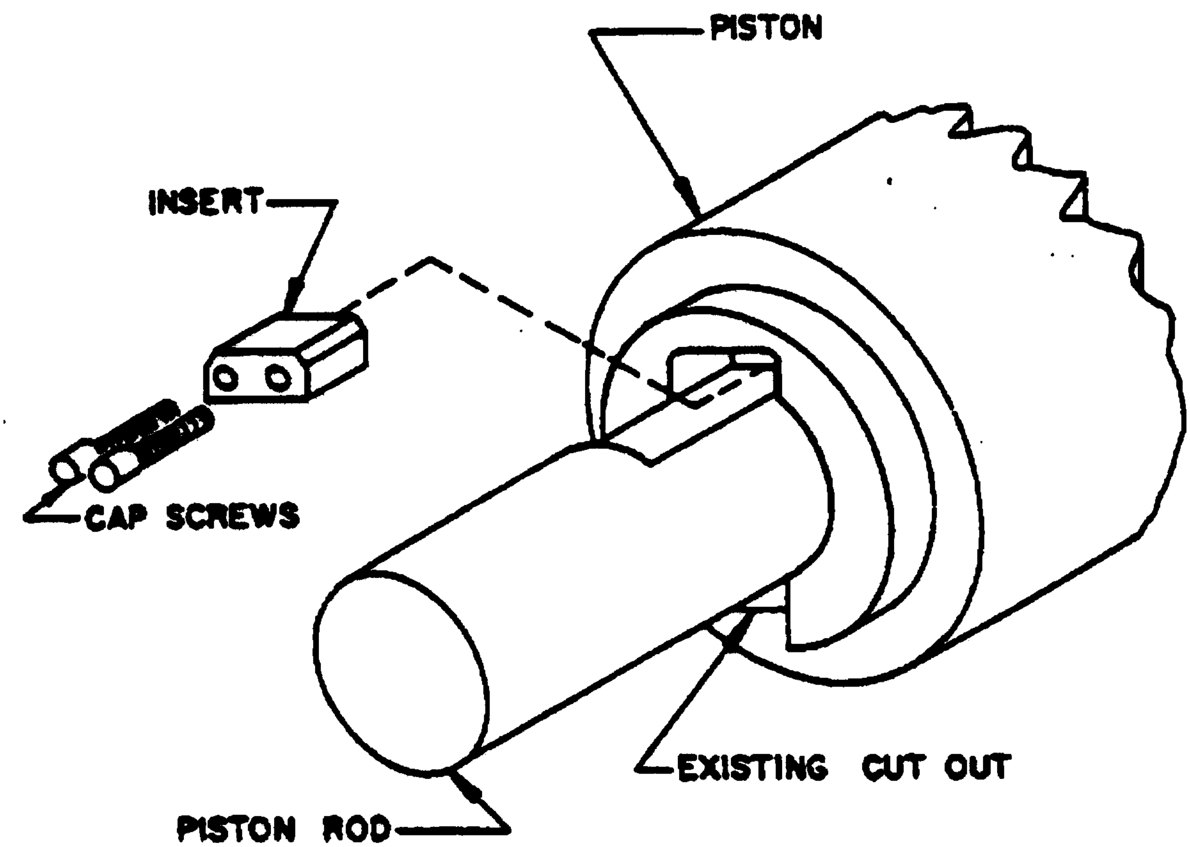


Figure 561-2-17. Hydraulic Cylinder Piston Retainer

561-2.8.2.7 Determining the Thickness of a New Shim. A coupling that was initially installed with the piston rod and guide cylinder rod in direct contact (no shim installed) is a special case. Although only few in number, such installations do exist. If clearance holes and tapped holes in these installations are in alinement after the coupling is torqued to a value per Table 561-2-5, a shim does not have to be installed. However, since the original installations did not specify a torque value, it is quite likely that the currently specified torque will necessitate use of a shim. If so, determine the thickness of the required shim as follows:

1. Aline the tapped holes in the rods with the clearance holes in the coupling (the assembled condition with the locking bolts removed).
2. Attach a dial indicator to one of the rods, with the indicator plunger in contact with the end of the coupling.
3. Torque the coupling to a value per Table 561-2-5, making certain neither rod rotates.
4. Record the movement measured on the dial indicator.

5. Since a very thin shim is difficult to manufacture, it is suggested that the shim installed have a thickness of 1/P inches plus twice the measurement obtained in step 4. (P represents the threads per inch in the coupling and 1/P is the movement of the rod relative to the coupling on one complete rotation.)

6. Elongate the hole on the piston rod end of the coupling 1/P inches toward the nearest edge of the coupling. Elongation must be accomplished prior to reassembly.

NOTE

During installation, the coupling is first started on the guide cylinder rod one turn prior to threading on to the piston rod. This provides room for the shim and results in proper locking-bolt hole alinement. This procedure is also applicable during coupling reassembly.

561-2.8.2.8 Maximum Allowable Shim Thickness Changes. Addition/deletion of a shim or installation of a thinner/thicker shim in the coupling assembly changes the total length of the mechanical linkage between the control surface stock (yoke assembly) and the hydraulic cylinder piston. The primary concern regarding this change is that the clearance between the piston and the hydraulic cylinder head (when the control surface is in the hard over, mechanical hard stop, position) is affected. Shipbuilding specifications require that the cylinder piston clear the ends of the cylinder by at least 1/4 inch when the control surfaces are against the hardstops. Most cylinders have been designed to provide clearance of 1/2 inch or more. Therefore, it is recommended that if the thickness of the shim to be installed approaches 1/4 inch more, or 1/4 inch less, than the shim thickness originally specified on the applicable class drawings, the piston/head clearance be verified as outlined in paragraph 561-2.7.5.1.

561-2.8.2.9 Reassembly of Couplings. When reassembling the coupling, observe the same precautionary measure cited for coupling disassembly (paragraph 561-2.8.2.3). To prevent the shim from falling out of its intended position once the coupling is started on both rods, secure the shim to one of the rods, using a small patch of lightly applied contact cement. In some installations, a flat head machine screw is used to hold the shim to one of the rods. In these installations be sure that the screw is tightened in place before proceeding. The procedure for assembling a coupling will differ according to the initial coupling installation and the maintenance performed. Procedures for five specific cases are as follows:

CAUTION

Cylinder piston rotation during assembly of couplings may subject equipment to undue strain and shall be avoided unless otherwise specified.

1. Case 1 - Original installation did not include shim. The dimensions of the new shim should be those determined in accordance with the instructions in paragraph 561-2.8.2.7. In this particular installation, the piston rod should be engaged in the coupling one full turn less than is the guide cylinder rod. Secure the shim to one rod, as discussed above, and engage the guide cylinder rod in the coupling one full turn. Engage the coupling to the piston rod by rotating only the coupling. Verify proper orientation of the tapped holes in the two rods, using the scribed lines (paragraph 561-2.8.2.3). Holding both rods from rotating, torque the coupling to a value per Table 561-2-8, stopping when the locking bolt clearance holes aline with the tapped holes in the rods. If alinement cannot be achieved with torque within the specified range, redetermine the proper shim thickness

and repeat the above process until alinement is obtained. (See paragraph 561-2.8.2 for requirements.) Install locking bolts in accordance with paragraph 561-2.8.2.2.

2. Case 2 - Original installation included shim. The dimensions of the new shim should be those determined in accordance with the instructions in paragraph 561-2.8.2.6. Secure the shim to one rod as discussed previously, and start both rods into the coupling at the same time by rotating only the coupling. Verify proper orientation of the tapped holes in the two rods, using the scribed lines (paragraph 561-2.8.2.3). Holding both rods from rotating, torque the coupling to a value per Table 561-2-8, stopping when the locking bolt clearance holes aline with the tapped holes in the rods. If alinement cannot be achieved with torque with the specified range, redetermine the proper shim thickness and repeat the above process until alinement is obtained. (See paragraph 561-2.8.2 for requirements.) Install locking bolts in accordance with paragraph 561-2.8.2.2.

3. Case 3 - Piston rod replaced. Install piston rods in accordance with paragraph 561-2.8.2.

4. Case 4 - Guide cylinder rod replaced. Install cylinder rods in accordance with paragraph 561-2.8.2.

5. Case 5 - Coupling replaced. If a new coupling is to be installed, it shall be furnished with locking bolt clearance holes not drilled since these holes must be alined to the existing locking bolt holes in the piston rod and the through-hull connecting rod. Using micrometers, measure the axial distance from the centerline of the locking bolt hole in each rod to some prominent point on the rod which will remain accessible when the coupling is installed. Secure the original coupling shim to the end of one rod and start both rods into the coupling at the same time by rotating only the coupling. While holding both rods from rotating, torque the coupling to a value per Table 561-2-8, stopping when the scribe lines (See paragraph 561-2.8.2.3, subparagraph 5) on the two rods are in axial alinement. (Reshim if necessary. Ensure that the shim used will provide proper piston to hydraulic cylinder head clearance.) Establish scribe lines on the end faces of the coupling using the scribe lines on the rods. Establish axial centerline locations for the locking bolt clearance holes on each end of the coupling. Using the micrometer dimensions obtained earlier, establish the fwd-aft location of the locking bolt clearance holes on each end of the coupling. Disassemble the coupling and drill the locking bolt clearance holes. Reassemble the coupling in accordance with paragraph 561-2.8.2.9, subparagraph 2 Case 2 and paragraph 561-2.8.2.

561-2.8.2.10 Additional Comments Applicable to Reassembly. Cases 3 and 4 in paragraph 561-2.8.2.9 specify torquing the piston rod. Precautionary information relative to rotating the piston rod on a number of ship classes is given in paragraph 561-2.8.2.4.1. On ships where assembly conditions necessitate piston rod rotation, the cylinder head should be removed following coupling assembly and the piston locking fasteners should be inspected for integrity. All assembly procedures in paragraph 561-2.8.2.9 are based on the assumption that during the initial coupling installation (ship construction), both rods were started on the coupling at the same time. If, during reassembly procedures, both locking bolt holes are out of alinement an equal amount proceed as follows:

1. Start the coupling on one rod before starting it on the other.

2. After assembling the coupling, verify the existence of proper clearance between the piston and the cylinder heads as specified in paragraph 561-2.7.5.1.

3. Replace and realine all feedback transmitter linkage and mechanical angle indicators.

4. Inspect all mechanisms for ruggedness, proper clamps, presence of all set screws, and security of all pins and fasteners.

5. Conduct an operational test of the complete system to verify proper functioning.

561-2.8.3 STEERING AND DIVING CONNECTING RODS. Two connecting rods are used in most installations. One, the guide cylinder rod, is connected to the hydraulic cylinder by the coupling and to the crosshead piston with a threaded connection. This rod penetrates the pressure hull and transmits the linear force generated at the hydraulic cylinder to the crosshead piston. Alinement of this rod with the hydraulic cylinder piston rod is very important, because wear of bearing surfaces and packing rings in the guide cylinder cover and hydraulic cylinder head will accelerate with misalinement. For further information on the subject refer to paragraph 561-2.8.4.1. The other connecting rod usually found in steering and diving gear is commonly referred to as the dogbone because of its shape. This rod is located outboard of the pressure hull. It is connected to the crosshead piston and tiller by means of pins. This arrangement allows for rotary motion at the crosshead piston and tiller, as the tiller swings through an arc while turning the control surfaces. For a typical arrangement of these two rods refer to Figure 561-2-13 and Figure 561-2-14.

561-2.8.3.1 Loose Coupling. Couplings connecting the hydraulic piston rod to the through-hull connecting rod occasionally loosen. This loosening may cause noise or undesirable mechanical working of the joint. If a loose coupling is detected, retorque the coupling following the procedures provided in paragraph 561-2.8.2.1.

561-2.8.3.2 Removal of SSN 688 Class Through Hull Connecting Rods. Removal of the steering and stern diving through hull connecting rods through the engine room access is impractical because of the long length of the rod. NAVSEA Dwg. 100-5789854 provides guidance and details for removal of these rods using access cuts in the ship's stern section.

561-2.8.4 CONNECTING ROD LUBRICATION. Since rotary motion exists at the tiller and crosshead (piston or slide) pins, bushings are installed in the outboard (dogbone) connecting rod. Various SHIPALTS install bushings in tiller arms where the original design does not provide this feature. Some submarine TRSs provide for installing bushings in guide pistons as a method of restoring piston wrist pin bores that are enlarged due to wear or repair machining. Thrust washers are installed between the bearing faces of the connecting rod and the adjoining surfaces on tillers and pistons. On most submarine classes, each end of the connecting rod receives lubrication via either local grease fittings or a centralized system using manifolds or distribution valves located within the pressure hull. On older submarine classes where only local fittings are installed, the ship must be surfaced or, for the stern planes and rudder, drydocked in order to lubricate the connecting rods. Until such time that nonmetallic bushings and washers that require no lubrication are installed, periodic greasing in accordance with PMS and SMMS MRCs is required. The **Submarine Greasing Handbook** , NAVSEA T6350-AA-HBK-010, provides general information about greasing components, greasing requirements, and greasing methods.

561-2.8.4.1 Rod Alinement Problems. If the connecting rods for the guide cylinders and their associated hydraulic cylinder piston rods are not properly alined prior to coupling installation, the following problems may be experienced:

1. Scratching and galling of the rods.
2. Premature packing wear and leakage.
3. Bending of a rod.

561-2.8.4.1.1 The most common alinement problem has been the scoring and galling of the stern diving guide cylinder connecting rod, primarily on the lower side, as it comes into contact with the guide cylinder packing gland retainer. Even though misalinement may not result in rubbing contact when the ship is surfaced, there may be a problem when the ship submerges. Pressure hull deflection resulting from submergence pressure can result in significant relative motion between the guide cylinder and the hydraulic ram. To minimize potential problems, the hydraulic cylinder piston rod must be carefully alined with the guide cylinder connecting rod. The alinement procedure in paragraph 561-2.8.4.2 should be used following removal and reinstallation of a hydraulic ram or guide cylinder connecting rod. Whenever damage to a guide cylinder connecting rod or hydraulic cylinder piston rod resulting from misalinement is suspected, the alinement verification procedure in paragraph 561-2.8.4.4 should be conducted.

561-2.8.4.2 Rod Alinement Procedure. For the rod alinement procedure, the coupling must be removed and the ship should be in a dry dock if no positive means to restrain the control surface is available.

WARNING

Any movement of control surfaces while coupling is removed can result in the guide cylinder rod's impacting against the hydraulic cylinder piston rod with sufficient force to cause loss of life or dismemberment. The control surfaces must be restrained to prevent movement and the general area of the connecting rods must be posted as a danger area.

561-2.8.4.2.1 The alinement procedure is as follows:

1. Prior to removal of the coupling, record the radial clearance between the through hull connecting rod and its packing retainer and the hydraulic cylinder piston rod and its packing retainer in accordance with the procedure provided in paragraph 561-2.8.4.4.

2. Remove the coupling and position the through hull connecting rod and the hydraulic cylinder piston rod in a position corresponding to the zero degree position of the control surface. Place a straight edge parallel to the rods as shown in Figure 561-2-18. The straight edge shall be straight to +.0015 inch over its total length, with the total length of the straight edge such that the ends of the straight edge fall within one (1) inch of the hull packing gland and the hydraulic cylinder packing gland. Take measurements A and A1 within one (1) inch of the end of the straight edge and B and B1 within one (1) inch of the end of the rod thread reliefs.

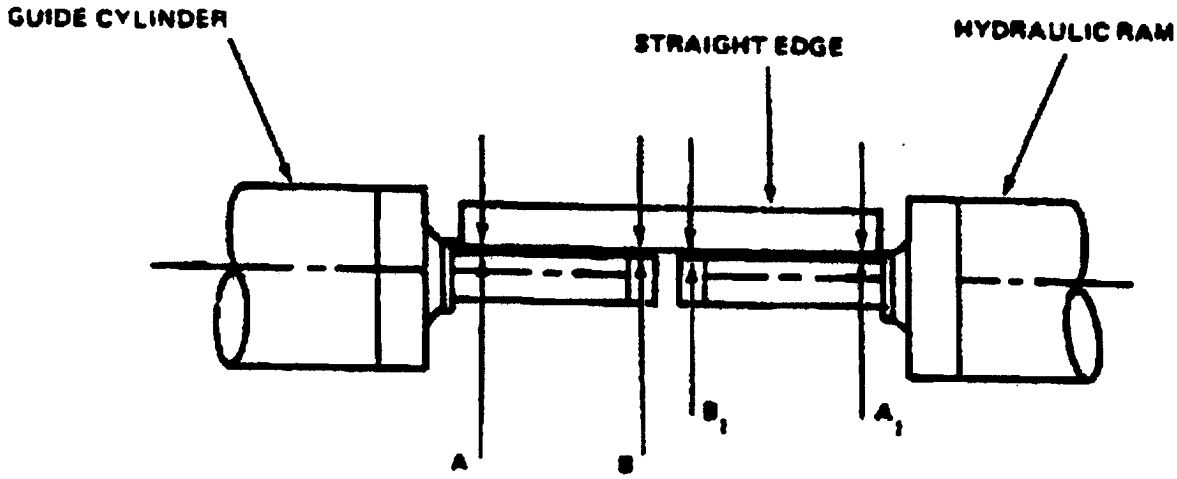


Figure 561-2-18. Rod Alinement Check With Coupling Removed

NOTE

It may be necessary to place plastic shims between the rods and their packing retainers in order to keep the rods centered after the coupling is removed. Exercise care when installing shims to avoid damaging the adjacent packing.

3. When alining rods of the same diameter, take measurements of A, A1, B, and B1 dimensions at the 12 and 3 o'clock positions to check alinement in the vertical and horizontal planes respectively. If all measurements are zero, alinement is perfect. If any dimension is greater than .005 inch, take corrective action.

4. When the rods are of different diameter, mount the straight edge on the larger diameter rod (i.e. points A and B on the rod of larger diameter) and take measurements between the straight edge and the smaller diameter rod (i.e. points A1 and B1 on the rod of smaller diameter). Take measurements at the 12 and 6 o'clock positions to check alinement in the vertical plane and at the 3 and 9 o'clock positions to check alinement in the horizontal plane. If all A1 and B1 measurements are equal, alignment is perfect. If the difference between A1 and B1 in a single plane is greater than .005 inch, take corrective action. (Example: If A1 at 3 o'clock is .200 inch and B1 at 3 o'clock is .206 inch, the difference of these readings taken in the horizontal plane is greater than .005 inch and corrective action is necessary.) If the difference between A1 and A1 180 degrees opposite in a single plane or B1 and B1 180 degrees opposite in a single plane is greater than .010 inch, take corrective action. (Example: If A1 at 3 o'clock is .200 inch and A1 at 9 o'clock is .211 inch, the difference of these readings taken in the horizontal plane is greater than .010 inch and corrective action is necessary.) (Alternate Method) (See Table 561-2-9) When the rods are different diameter, mount the straight edge parallel to the center line of the larger diameter rod, diameter D, (i.e. points A and B on the rod of larger diameter) and take measurements between the straight edge and the smaller diameter rod, diameter D1, (i.e. points A1 and B1 on the rod of smaller diameter). Take and record measurements at the 12 or 6 o'clock positions to check alignment in the vertical plane and at 3 or 9 o'clock positions to check alignment in the horizontal plane. If all A1 and B1 dimensions are equal, alignment is perfect. If the difference between A1 and B1 in a single plane is greater than .005 inch, take corrective action as alignment is unsatisfactory. If the difference between A and A1 (or B and B1), when adjusted for different rod dimensions, is greater than .005 inch, alignment is unsatisfactory.

5. If the thickness of the hydraulic cylinder foundation shims must be adjusted in order to aline the rods, the existing cotter pin holes in the mounting bolt/studs may no longer aline with the holes in the original nuts. In this case, the use of elastic stop nuts is preferred to drilling new holes, because the stud will be weakened by the drilling. Table 561-2-5 provides standard part numbers for self-locking nuts.

Table 561-2-9 RODS OF DIFFERENT DIAMETERS (ALTERNATE METHOD)

Measurement Positions (See Figure 561-2-18)	Actual Dimensions				Required
	A	B	A1	B1	
Vertical Plane (12 or 6 o'clock) Horizontal Plane (3 or 9 o'clock)					When rods are different diameters: (1) if the difference between A1 and B1 in a single plane is greater than 0.005 inches, alignment is unsatisfactory. (2) if the difference between (A1+R1) and (A+R) or between (B1+R1) and (B+R) in a single plane is greater than 0.005 inches, alignment is unsatisfactory.
Rod Diameter D =		D/2 = R =			
Rod Diameter D1 =		D/1 = R1 =			

Table 561-2-9 RODS OF DIFFERENT DIAMETERS (ALTERNATE METHOD) - Continued

Vertically: (A1-B1) = (A1+R1) - (A+R) = (B1+R1) - (B+R) =	
Horizontally: (A1-B1) = (A1+R1) - (A+R) = (B1+R1) - (B+R) =	
NOTE: The misalignment calculated using the above equations will result in a positive or negative number. The absolute value of this number is the magnitude of misalignment. The positive or negative sign will indicate the direction of misalignment.	

561-2.8.4.3 SSN 637 Class Fairwater Diving Hydraulic Cylinder Alinement Procedure

NOTE

For SSN 637 class fairwater planes, problems have been reported in assembling the piston rod to the through hull connecting rod. Due primarily to tight thread fit and screwing into a blind hole, air and excess lubricant have no easy way to escape; consequently, assembly can result in sufficient stress on the threads to cause galling. An acceptable solution to prevent this is to cut a 1/16″ wide groove the length of the thread to the depth of the thread root diameter in the male thread. Use of this procedure in applications other than defined above requires SPECIFIC approval from NAVSEA. This alinement procedure should be accomplished with the through hull connecting rod and hydraulic cylinder piston rod in positions corresponding to the zero degree position of the control surface. The alinement procedure is as follows:

1. Completely disassemble the fairwater diving hydraulic cylinder. With all internal components removed, reinstall the body of the external cylinder in the bridge trunk.

NOTE

The only fairwater diving gear that should be in the trunk at this time is the body of the external cylinder and the through hull connecting rod. Perform any required repairs of the ID of the hydraulic cylinder prior to accomplishing this procedure. The alinement check must be accomplished with the hydraulic cylinder ID rework complete.

2. Manufacture a ″dummy″ inner piston rod from aluminum stock as shown in Figure 561-2-20. The rod will have the same dimensions as the actual inner piston rod. Thread the ″dummy″ piston rod into the through hull connecting rod.

NOTE

Fairwater plane components that are in the bridge trunk following the above should consist of the body of the outer hydraulic cylinder, the through hull connecting rod and the dummy inner piston rod. See Figure 561-2-21.

3. Center the through hull connecting rod within its packing gland by rigging around the lower flanged end of the rod. The through hull connecting rod is considered centered when uniform feeler gauge measurements are obtained as discussed in paragraph 561-2.8.4.4. If accessible, also verify that the through hull connecting rod is centered within the bushing. Care should be taken to ensure there is no movement of the through hull connecting rod/″dummy″ rod assembly after centering. Shims of uniform thickness may be inserted between the through hull connecting rod and packing gland at four locations to aid in securing the through hull connecting rod. The shim thickness should be the same as the feeler gauge measurements. Shimming between the through hull connecting rod and bushing may be done as well.
4. With the operating rods centered, measure the radial clearance between the OD of the ″dummy″ inner piston rod and the ID of the hydraulic cylinder. Take measurements at four locations 90 degrees apart from the upper, middle, and lower portions of the hydraulic cylinder (total of 12 measurements). Measurements should be taken in the FWD/AFT and PORT/STBD positions. Alignment is considered satisfactory when each location's measurements are within 0.002 inch of each other.

NOTE

While recording measurements, continually verify that the through hull connecting rod remains centered within the packing gland. If any movement has occurred, start again with step 3.

5. This procedure is to be accomplished after all other rework of the fairwater diving gear is completed and prior to final reassembly.

561-2.8.4.4 Rod Alinement Verification. Verified alinement should be as follows: After every coupling reassembly and whenever through hull rod or hydraulic piston rod wear or damage resulting from misalinement is suspected.

CAUTION

Shut isolation valves and tag control valves as necessary to prevent ram movement during alinement verification.

1. With the control surface first at zero degrees and then at each mechanical hardstop position, measure and record the radial clearance between the through hull connecting rod and its packing retainer.
2. Take measurements at four locations (3, 6, 9 and 12 o'clock) around the rods.
3. Repeat steps 1 and 2 to measure the clearances for the hydraulic cylinder piston rod and its packing retainer.
4. Uniform radial clearance between the through hull connecting rod and its packing retainer, and the hydraulic piston rod and its packing retainer is evidence that the retainers are centered around the rods and that the rods are alined. A radial clearance less than .002 inch implies possible misalinement of the rods and the need for corrective action.

561-2.8.5 STEERING AND DIVING GUIDE CYLINDER ASSEMBLIES. The following discussion is general in nature and not descriptive of a particular ship class. For details applicable to a particular ship refer to selected record data such as Ship's Information Book or to assembly and detail drawings. For a typical guide cylinder assembly see Figure 561-2-19.

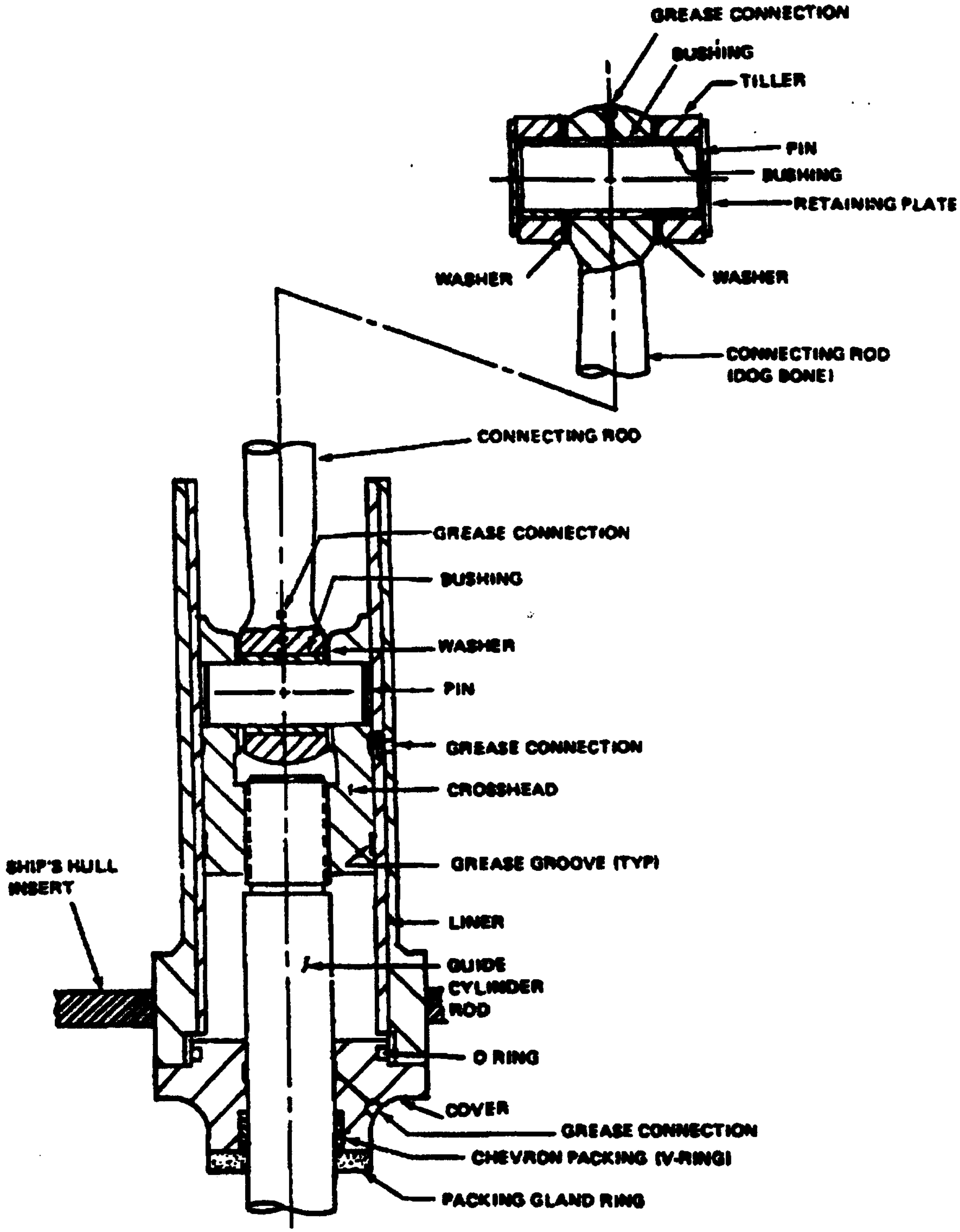


Figure 561-2-19. Guide Cylinder and Connecting Rod

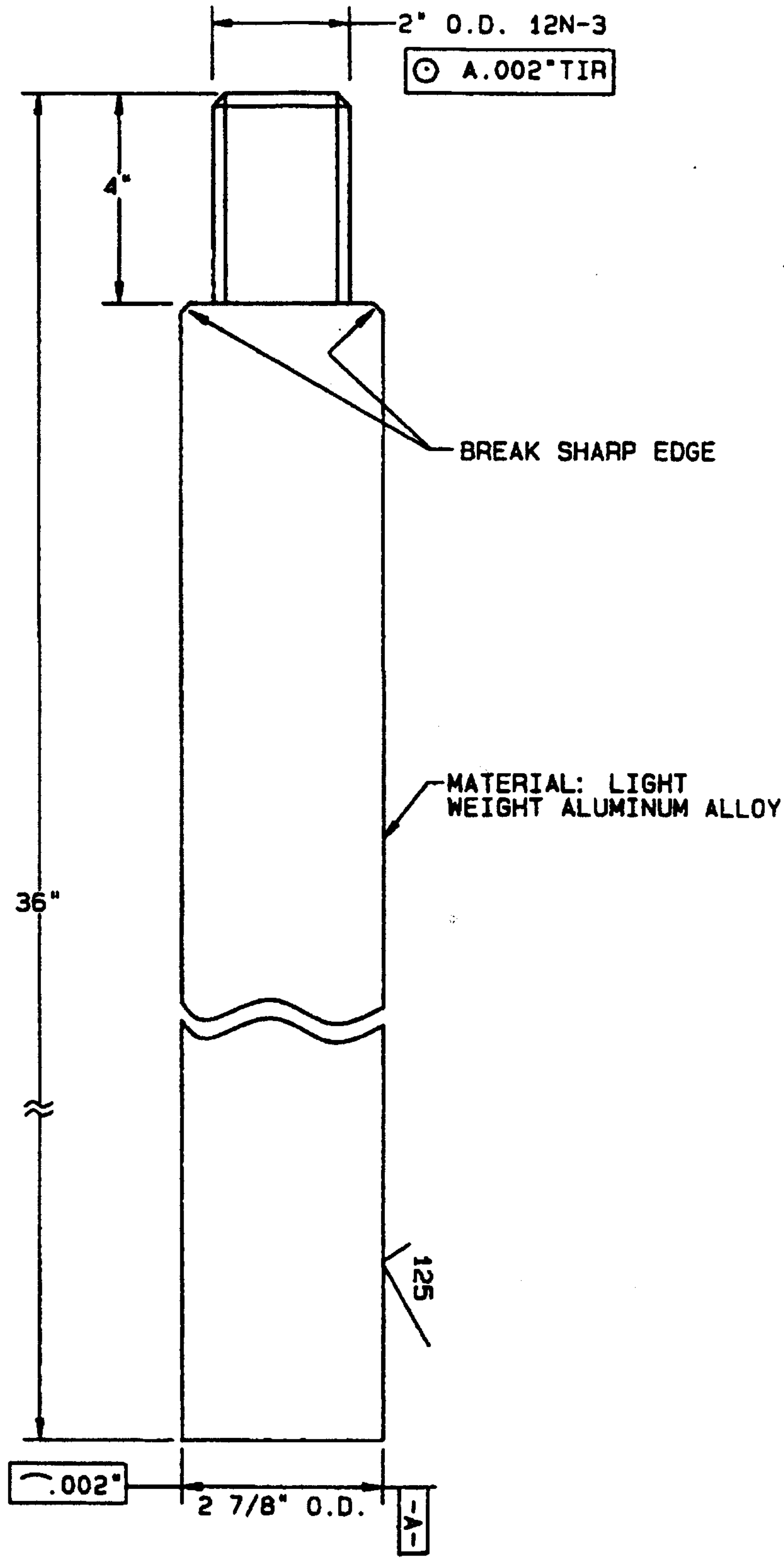


Figure 561-2-20. ″Dummy″ Inner Piston Rod

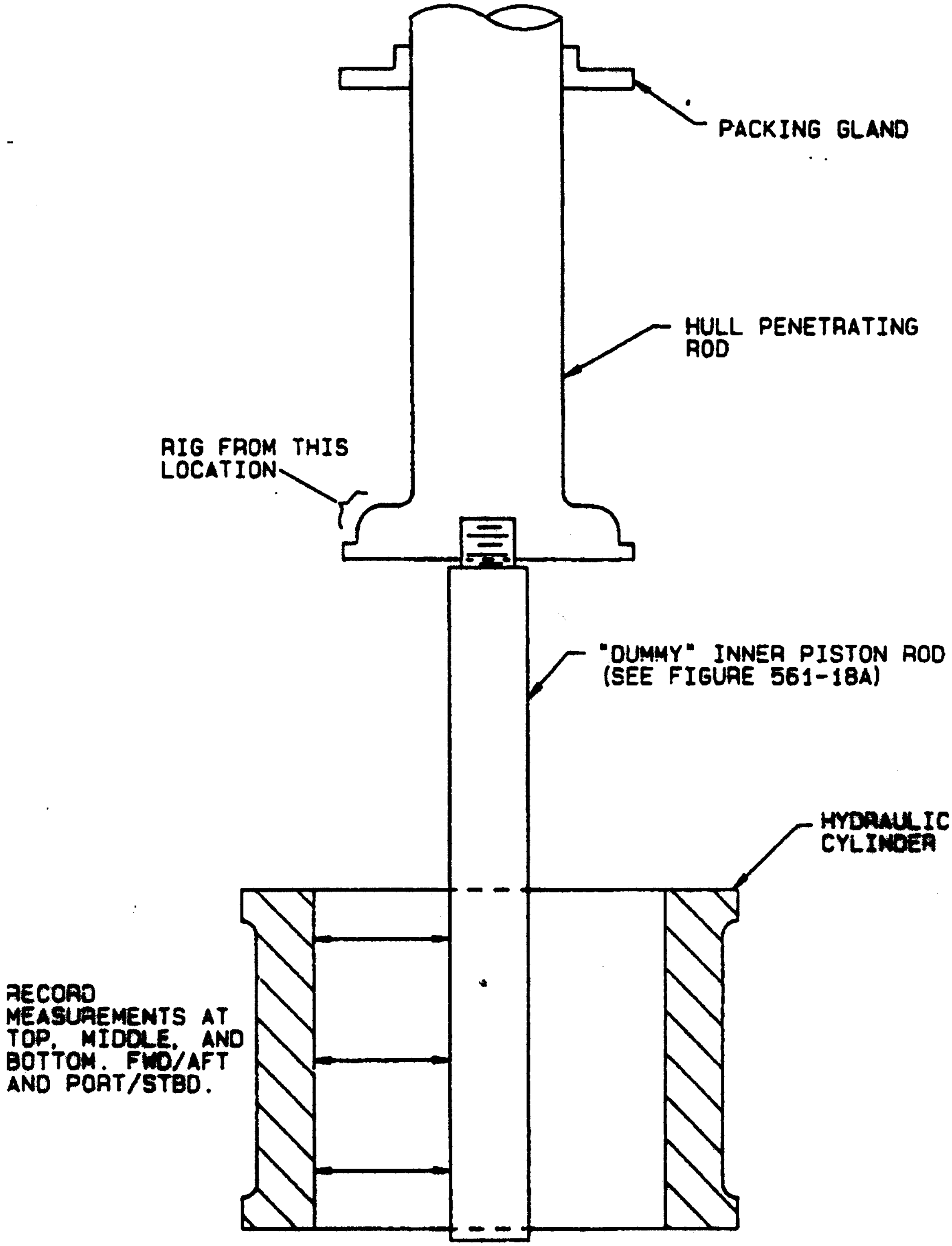


Figure 561-2-21. Fairwater Planes Ram Alinement

561-2.8.5.1 Guide Cylinder Construction. Several components are combined to form the guide cylinder assembly (see Figure 561-2-19). There are some assembly variations among classes, but the basic designs are similar. The main purpose of the guide cylinder is to provide a means for the crosshead piston to be supported while transmitting hydraulic cylinder forces. Guide cylinder assemblies are comprised of one of the following cylinders in addition to various other components discussed in paragraphs 561-2.8.5.1.1 through 561-2.8.5.1.3:

1. The steering and stern diving cylinder. Constructed of either steel or Monel, this tube is welded to the pressure hull at the tube's forward end and to the aft ballast tank bulkhead at the tubes other end.
2. The fairwater diving cylinder. This cylinder is usually a steel tube welded or bolted to the bridge access trunk at its bottom end, with the upper end supported by ship's structure within the fairwater itself.
3. Bow diving guide cylinder. Generally constructed of steel, this cylinder is located in the free flood area forward of the pressure hull.

561-2.8.5.1.1 Most of the steering and diving cylinders penetrating the pressure hull or bridge access trunk have a cast copper-alloy cover bolted onto the inboard end. This cover contains both a bearing surface for the connecting rod to ride on and, at its inboard end, a counterbore for packing around the connecting rod. The packing is held in place with a separate cast retainer that is in turn bolted to the cover. When installed correctly, the chevron or V packing will prevent seawater from entering the ship. For packing installation guidance refer to **NSTM Chapter 078, Seals** . External seal leakage criteria for hydraulic cylinders per Table 561-2-2 may be used for guide cylinder cover V-ring or chevron seals.

561-2.8.5.1.2 Several ship classes do not have a bolted cover on the fairwater diving guide cylinder. These ships have the inboard end of the guide cylinder cast with the cylinder, forming a closed end. The only opening is where the rod penetrates. A packing counterbore and packing retainer, as noted above, are provided.

561-2.8.5.1.3 Steel guide cylinders use a gun metal or other copper-based alloy liner that provides a bearing surface for the crosshead piston to ride on. The interface between the steel guide cylinder and this liner has the potential to cause corrosion of the steel guide cylinder, i.e., galvanic corrosion in a seawater environment. To preclude this action, one of two methods is used. The most common is to apply a synthetic rubber sealant to the area of the interface. The other method is to weld the two pieces together at this joint. If the liner is cut back to remove corrosion, and, as a result, leaves insufficient bearing area for the guide piston (i.e., if any portion of the guide piston grease groove or 10% of the piston bearing area overhangs the guide cylinder liner), the bearing area must be restored. If for this or other reason the liner is removed, replace a gun metal liner with a monel (NI-CU) liner per QQ-N-281. Seal the joint between monel liner and steel cylinder by welding.

561-2.8.5.2 Guide Cylinder Liner Rubber Sealant. To prevent the entrance of seawater, a rubber sealant must be applied to the joint between the guide cylinder and the liner. This joint must be prepared for the sealant as follows:

1. Clean to bare metal (i.e., until free from all foreign substances such as scale, corrosion, and paint) both the joint to be sealed and a 1/2-inch area on each side of the joint.
2. After initial preparation is completed, wipe down the area to be sealed with an oil-free solvent such as trichloro-trifluoroethane conforming to MIL-C-81302. No surface primer is required prior to sealant application.

3. Apply sealant with an extrusion gun or spatula. If an extrusion gun is used, use a 1/8- to 3/16-inch diameter nozzle held so that it is perpendicular to the joint or seam. Exercise care with either method to prevent formation of air pockets or voids.

561-2.8.5.3 Guide Cylinder Liners Welded in Place. The guide cylinders that have the liner welded in place at the interface joint do not require the weld to be removed unless dye penetrant or magnetic particle inspection shows that a defect in the welded joint may exist. If cracks or other defects exist, the defective area is to be excavated to sound metal and repaired as necessary.

561-2.8.5.4 Guide Cylinder Covers and Packing Retainers. Covers and retainers are normally a cast copper alloy such as nickel aluminum bronze. These two pieces form a nonredundant pressure hull boundary; therefore it is imperative that they be maintained in good condition. Maintenance Requirement Card URO-MRC-015 addresses required inspections for these items (see paragraph 561-4.3.1). The packing gland retainer fits very closely with the connecting rod; misalinement of the rod may reduce this clearance to the extent that the rod will rub on the retainer and both will be damaged. If a through hull connecting rod is rubbing the packing retainer, corrective action short of realinement of the rods per paragraph 561-2.8.4.3 shall consist of either (1) increasing the diametrical clearance between rod and packing retainer to a maximum of 0.030 inch by increasing the ID of the packing gland, or (2) performing ShipAlts SSN 2830 or SSBN 1963 for applicable ships to obtain a larger diametrical clearance. Larger clearances are acceptable (if shown on applicable drawings) for installation in which V-ring adapters of duck and synthetic rubber with an approximate hardness of 70 durometer (D scale) are used to reduce extrusion. (Refer to SHIPALTS SSN 2830 and SSBN 1963). If the clearance between the guide cylinder cover and connecting rod becomes excessive, Appendix F may be used to repair the guide cylinder cover in lieu of replacement.

561-2.8.5.5 Guide Cylinder Piston. Within the guide cylinder is a closely-fitted piston. This piston, a casting made of a copper alloy such as nickel aluminum bronze, provides for the transition of liner motion from the hydraulic cylinder to the rotary motion required to operate the tiller. With the exception of the SSN 637 Class fairwater diving gear, which uses tracks instead of a piston, all other control surface gear uses a crosshead piston. The guide cylinder connecting rod is threaded into the forward end of the piston and fixed in place with either a jamnut, pin or both. When reassembling the through hull connecting rod with the guide piston, ensure that the threads on the rod are properly coated with sealant PR-380-M or equal. The tiller to crosshead rod (dogbone) is connected to the crosshead piston with a through pin that allows for rotation of this rod. Appropriate bushings are installed in the rod and crosshead to provide a bearing surface that in some classes is lubricated from a grease fitting located outboard and in others is lubricated through an internal grease manifold. The crosshead piston is grease-lubricated from within the ship, with the crosshead piston in the zero plane angle position. This piston is to be inspected periodically to determine the extent of corrosion and dealuminization. Because of the work involved, this inspection is usually done only during ship overhaul, unless abnormal operation or noise indicates the existence of a problem. A slapping noise may indicate excessive diametral clearance between the piston and guide cylinder, whereas lost motion between the hydraulic cylinder and control surfaces may indicate that either the connecting rod threaded connection is loose or the pin bushings are worn. Table 561-2-11 provides maximum operating cycle freeplay criteria for stern planes, fairwater planes, and rudder tiller and guide piston (or wrist) pin connections. For those guide pistons that do not have pin bushings installed, Appendix G may be used as a guide for installing bushings in lieu of piston replacement if bores are worn excessively.

561-2.8.6 TILLERS AND YOKES. Generally, the tiller used for steering and stern diving gear is cast integrally with its respective yoke. The integral tiller and yoke assembly used for steering and stern diving is mounted on the ship's axial centerline with a stock fitted between each control surface and the yoke. Taper fit and draw keys are usually used on each end of the stocks to hold them fast to corresponding tapered holes in the yokes and control surfaces. On some ships, the stocks are welded to the control surface hub, with tapers and keys used only at the yoke connection. Again, keys are installed at the interface of the stocks, yoke, and control surfaces to transmit torque (see Figure 561-2-25 and Figure 561-2-26). The tiller and yoke are preserved externally with a protective coating of glass, reinforced plastic or paint. Internal yoke areas, where the stocks are fitted, are filled with a preservative compound such as per MIL-C-11796 Class 1A for hot application, or per MIL-C-16173 Grade 1 for cold application; however the hot application is preferred. Maintenance is limited to verifying that the protective compounds are in good condition and that pitting has not exceeded allowable limits and weakened the component. Internal yoke surfaces must be checked periodically to ensure that seawater has not leaked in, displacing the protective compound or corroding the metal of either the yoke or stocks. Fairwater planes tillers for most classes of SSNs and SSBN 726 class are forged directly onto the stock. On SSBN 616/627 and 640 Class submarines and a few earlier classes, the ″tiller″ is a bolt-on/clamp-on assembly comprised of a forward half, or tiller, and an after half, called the tiller cap. These are bolted together on the one-piece stock and provided with keys to transmit torque to the planes (see Figure 561-2-14). Maintenance problems associated with bolt-on fairwater tiller-stock-bearing assemblies are often identified following a report of bearing noise. If stock bearing clearances and the quality of lubrication indicate that bearings are not the problem, then tiller-thrust sleeve-stock assembly loosening is the likely cause. The factors, usually in combination, which cause tiller- thrust sleeve-stock assembly loosening are (1) loose thrust sleeve assembly fasteners, (2) loose tiller nuts, (3) excess radial clearance between tiller and stock, and (4) loose tiller keys. This may be confirmed by performing a dial indicator inspection of the stock bearing clearance and the tiller/bearing housing relative motion as follows:

a. Measure the stock bearing clearances using dial indicators and ship's hydraulics. Ship's hydraulics are used to move the planes in and out of the rise hardstop. Mount dial indicators on port and starboard bearing housings with the indicator plungers reading the movement of the inboard ends of the outer sleeves (preload dial indicator to approx 0.050″. See location of outboard indicator in Figure 561-2-22. With the planes in the rise hardstop, zero the dial indicator. Slowly move the planes toward dive (usually about 3 degrees is sufficient). The dial indicator needle will move rapidly for a moment, remain steady briefly, then move erratically as the plane rotates. The clearance reading must be taken after the initial rapid movement while the needle is steady.

NOTE

> For ships with SHIPALT SSBN 1996, stock bearing diametral clearances may be taken by mounting the dial indicator on the inboard side of the bearing housing reading directly to the stock (with the keeper ring removed). See Figure 561-2-23.

b. Measure the relative movement between the tiller and the bearing housing. Mount dial indicators on port and starboard bearing housings with indicators on port and starboard bearing housings with indicator plungers reading the movement of the outboard ends of the thrust sleeve assemblies. See location of inboard indicator in Figure 561-2-22. Use ship's hydraulics to move the planes in and out of the hardstops as in step a., above.

c. Subtract the bearing clearance readings obtained in step a. from the relative movement readings obtained in step b. If the differences on both sides are 0.010 inch or less, the tiller is considered to be satisfactorily tight for operating cycle considerations.

d. If the difference between the inboard dial indicator and the outboard dial indicator exceeds 0.010 inch, the tiller/thrust sleeve/stock assembly is loose. Repair and troubleshoot the cause/causes as follows:

    1. Loose thrust sleeve assembly fasteners. One at a time, remove, clean, inspect, reassemble and tighten the fasteners that hold the thrust sleeve halves together and that hold the assembly to the tiller/tiller cap. Use torque values provided by NAVSEA 0990-LP-091-6010 Appendix E. Repeat steps b. and v., above. If the difference on either side is still greater than 0.010 inch, looseness in the tiller is possible. Proceed to paragraph 561-2.8.6.d.(2), below, to determine if looseness is a result of loose tiller nuts.

2. Loose tiller nuts. Install SHIPALT 2012D, if it is not already installed. See paragraph 561-2.8.4.4, below. If SHIPALT 2012D is already installed, remove, clean, inspect, reassemble and tighten the nuts one at a time. DO NOT REMOVE THE BOLT. Clean and inspect the threads on both nut and bolt. Thoroughly lubricate the nut and bolt threads and the bearing face of the nut. Torque the nut to 2000 ft. lbs. Measure the relative movement between the tiller and tiller cap in both the horizontal and vertical axes by moving the planes in and out of the hardstops using ship's hydraulics as described in step a. above and by locating dial indicators, as shown in Figure 561-2-24. No movement is allowed. Any movement indicates inadequate preload of the tiller fasteners and this step should be redone. If no relative movement occurs between the tiller and tiller cap, the tiller looseness is caused by excess radial clearance between tiller and stock or loose tiller keys. Contact NAVSEA for repair recommendations.

3. Excess radial clearance between tiller and stock or loose tiller keys. Repeat steps in subparagraphs b. and c., above. If the difference on either side is still greater than 0.010 inch, there is excess radial clearance between tiller and stock or loose tiller keys. See paragraphs 561-2.8.8 through 561-2.8.10, below, to inspect and repair.

561-2.8.7 LOOSE TILLER NUTS. On SSBN 616/627 and 640 Class ships, two tiller bolts are fitted and two are nonfitted. All are K-monel. Due to the differences in the size and material of the nuts, as detailed in NAVSEA Dwg. 616-518-2005259 and NAVSEA Dwg. 640-518-2118743, the torque required for 616 and 627 classes nuts is 1200 ft. lbs. and for 640 Class nuts is 2000 ft. lbs. Because of the tight clearance between the sides of the nut/bolt heads and the adjacent face of the tiller, it is impractical to fit a standard size socket on either the nut or bolt. Grinding the wall of the socket generally causes the socket to split when torque is applied. Consequently, an open-end wrench, fitted with a dynamometer and attached to a chain fall or a hydraulic jack, is sometimes used to achieve the required torque. It is an acceptable method, but is cumbersome and, when performed by untrained personnel, inadequate and inaccurate. In order to overcome this deficiency, SHIPALT SSBN 2012D replaces the existing tiller nuts with long nuts to permit socket engagement. If not already accomplished, SHIPALT 2012D should be accomplished if tiller/tiller cap movement is found. To ensure that proper clamping force is applied, the two upper tiller nuts should be torqued while ship's hydraulics forces the tiller cap into the rise hard stop. The two lower tiller nuts should be tightened while ship's hydraulics forces the tiller cap into the dive hard stop. Blocking or a small hydraulic jack may concurrently be used between the hard stop and the tiller cap arm to keep the nuts at a workable angle. The cotter pins for the nuts, piece 18 in both NAVSEA dwg 616-518-2005259 and NAVSEA dwg 640-518-2118743, are incorrectly specified as 3 1/2 inches long. Five inch long cotter pins should be used instead. The stock number for five inch long by 3/8 inch diameter cotter pins is NSN 5315-00-187-9521.

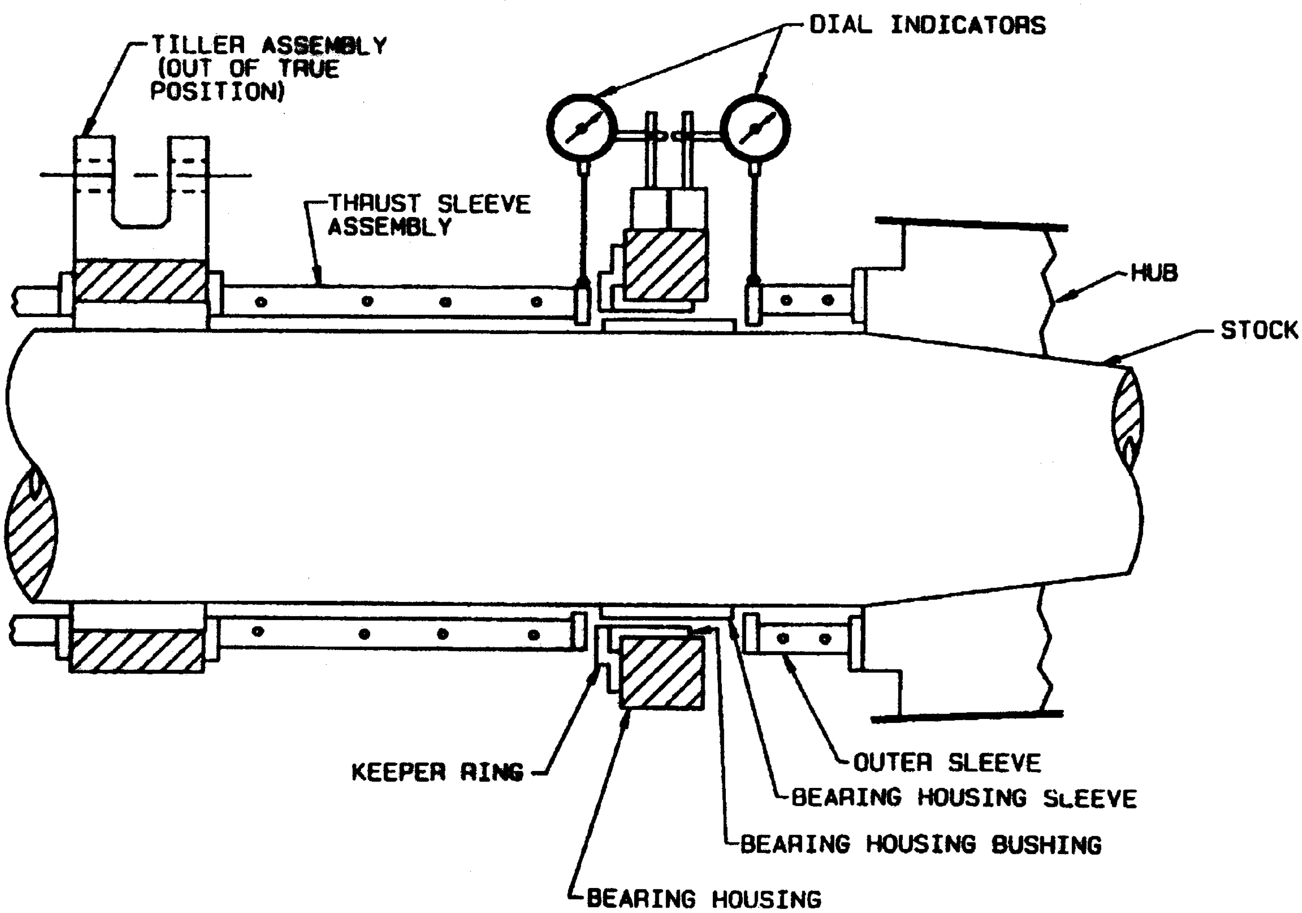


Figure 561-2-22. Stock Bearing Clearance Inspection

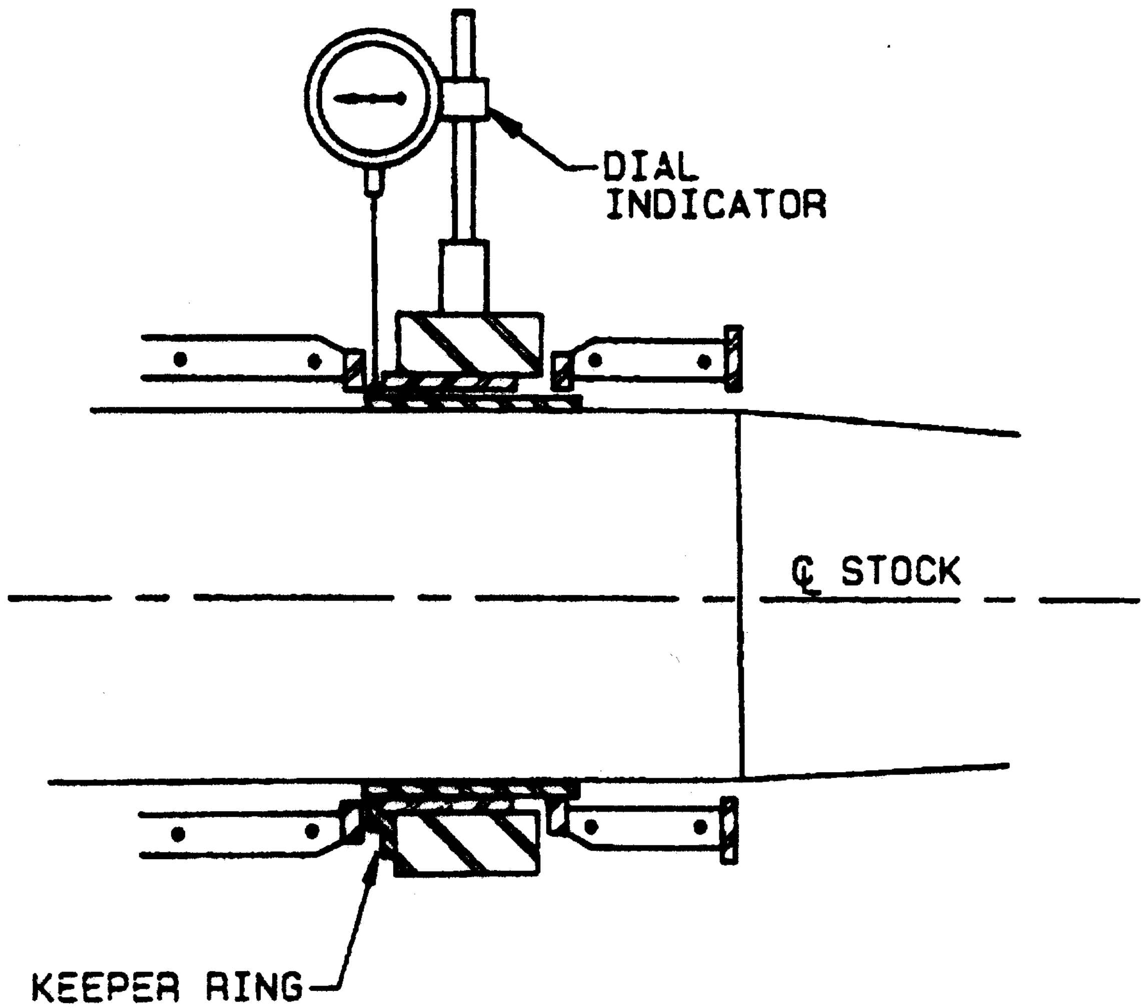


Figure 561-2-23. Stock Bearing Clearance Inspection for Ships with ShipALT SSBN 1996

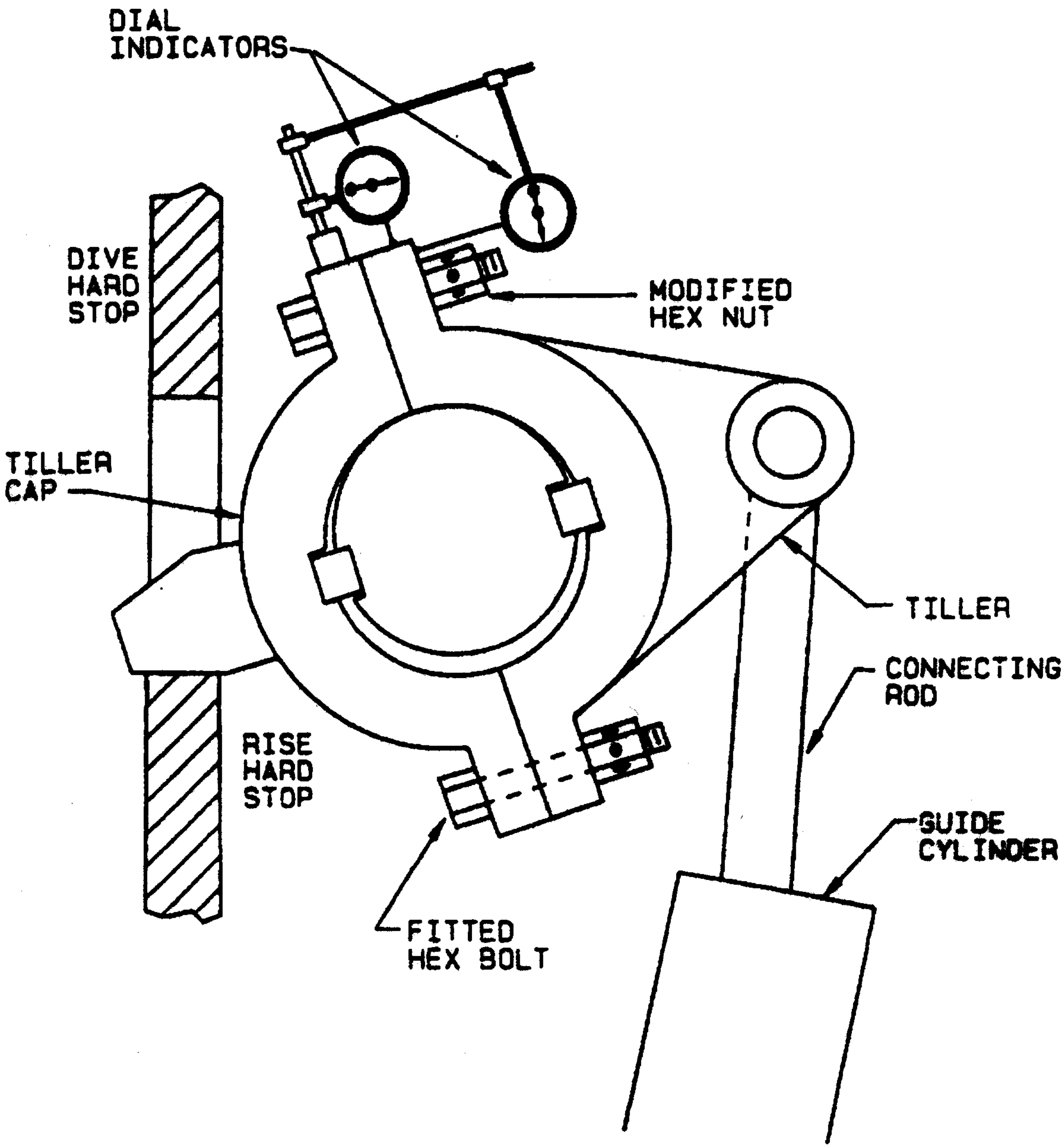


Figure 561-2-24. Fairwater Planes Tiller Inspection

561-2.8.8 EXCESS RADIAL TILLER/STOCK CLEARANCE. This clearance may cause wear and corrosion of the tiller/stock interface and motion-generated noise. Wear and deformation of these surfaces are greatly accelerated by any looseness, and once begun, this degradation is self-sustaining. A common, yet undesirable, repair procedure to remove excess radial clearance is to machine the inner faces of the tiller bolt face flanges. This draws the tiller/tiller cap closer together in the fore-and-aft axis, but it doesn't restore sufficient surface contact area and leaves a cavity for seawater intrusion and subsequent corrosion. This procedure may be used as a temporary repair, yet it must be followed by the preferred or permanent repair to restore design fit at the next shipyard availability. The preferred repair action is to accompany the machining of the inner flange faces with a machining of the tiller/tiller cap assembly inside diameter and keyways to restore design fit up with the stock and keys. Following any repairs there must be a check for relative movement between the assembled components in the horizontal and vertical axis.

561-2.8.9 CORROSION OF THE TILLER/STOCK MATING SURFACES. This is caused by seawater intrusion, and can be reduced or prevented by the following practices:

a. Ensure that fairwater thrust sleeves are properly assembled with the flanges in the vertical axis so that rust preventive compound (RPC) fill holes will be near the top of the sleeves. NAVSEA Dwg. 616-518-2007125 contains a note in zone 5B which incorrectly indicates that the thrust sleeves (piece 4) should be installed with the flanges oriented fore and aft. The orientation of piece 4 as drawn is correct. When filling the cavity formed by the thrust sleeves (piece 4) should be installed with the flanges oriented fore and aft. The orientation of piece 4 as drawn is correct. When filling the cavity formed by the thrust sleeves with RPC, ensure that the fill holes are at top dead center by rotating the fairwater planes as necessary.

b. Coat all mating surfaces of the tiller/tiller cap/keys/stock/thrust sleeves with anti-seize, zinc dust-petroleum thread compound, MIL-T-22361, prior to reassembly whenever the tiller is disassembled.

561-2.8.10 LOOSE TILLER KEYS. This is caused by normal working of the tiller and stock, and is accelerated by loose tiller nuts and corrosion. Design specifications permit a maximum side clearance of 0.001 inch on SSBN 616 and 627 Classes and 0.003 inch on SSBN 640 class. Operational ships may allow key to keyway clearance up to 25% greater than the maximum allowed by detail design drawings. Beyond this limit, keys must be replaced and/or keyways restored.

561-2.8.11 TILLER ARM BUSHINGS. For those ships that do not have bushings installed in the tiller arms and it would be desirable in order to correct defects in the pin bores, see Appendix H for applicability and details.

561-2.8.12 HARDSTOPS. Steering and diving hardstops are formed by protrusions cast onto the tillers and correspondingly built-up portions of the ship's structure. Stops are required in order to limit control-surface travel to approximately 2 degrees beyond normal operational angles whenever overhauling hydrodynamic forces from sea are experienced or in event of a hydraulic casualty. Strength and shape of stops must be maintained so that the stops will not fail with subsequent damage to the mechanical gear, hydraulic cylinder, or ship structure.

561-2.8.13 BEARINGS. There are four basic types of bearings used in submarine steering and diving gear: journal, spherical, bushing, and thrust. In order to obtain optimum service life and operation from these bearings, a lubrication system is installed and periodic greasing in accordance with applicable PMS-MRCs is required.

561-2.8.13.1 Bearing Lubrication. In order to obtain optimum service life and operation from steering and diving system bearings, a lubrication system is installed. Periodic greasing in accordance with PMS and SMMS MRC's is required. The **Submarine Greasing Handbook** , NAVSEA T6350-AA-HBK-010, provides general information about greasing components, requirements, and methods.

561-2.8.13.2 Journal Bearings. Journal bearings are comprised of two concentric cylinders. One cylinder, the sleeve, is shrink-fitted onto the stock; the other cylinder, the bushing, is shrink-fitted into a housing that is either welded or bolted to the ship's structure. These pieces are most often made from centrifugally-cast cobalt-based alloy. Journal bearings are usually used for the main support (inboard) and pintle bearings on all control surfaces. (See Figure 561-2-25 and Figure 561-2-26.) Bearing maintenance is limited to periodic greasing, usually from an inboard grease manifold, and to periodic measurements of the diametral clearance in order to determine when replacement is necessary. The lubrication system piping and fittings should be inspected and tested periodically to ensure that the grease is flowing freely from bearing and that all components are in good condition. Table 561-2-10 provides operating cycle criteria for stern planes, rudder, and fairwater stock bearing clearances.

561-2.8.13.3 Spherical Bearings. Spherical, or self-alining bearings generally consist of: (1) a sleeve, similar to that of a journal bearing, that is interference-fitted on a stock or pin, (2) a bushing, that is interference-fitted into a housing, and (3) a spherical shaped member, or ring, that is located between the sleeve and bushing. The inside surface of the bushing is formed to fit the spherical free-moving ring. The inner cylinder surface of the ring and the outside surface of the sleeve provide the rotating bearing surface, while the spherical surfaces of the ring and bushing permit a degree of axial rotation for self-alinement (see Figure 561-2-27 and Figure 561-2-28). The maintenance requirements for these bearings are the same as for the journal bearings. Inadequate lubrication of the bearing frequently causes the spherical bearing and sleeve to seize. This forces radial rotation to occur at the bushing-spherical bearing interface and causes accelerated wear of the bushing.

561-2.8.13.4 Thrust Bearings. Thrust bearings essentially are thin bearing rings used to absorb lateral thrust caused either by athwartship movement of the stern and fairwater diving planes or by the vertical load of the rudder (see Figure 561-2-25 and Figure 561-2-26). These units are made from cobalt-based alloy, copper alloy, or other material. Maintenance for these bearings is the same as for journal bearings.

561-2.8.13.5 Bushings. Bushings are used at each end of the dogbone and in the tiller arms and guide cylinder piston. Bushings, usually made of bronze alloy, are pressed into their respective bores. Sleeves are not usually used (except on SSBN 726 Class where the bushing and pin sleeve are made of stellite) as the pins provide a suitable bearing surface (see Figure 561-2-19). When excessive wear or clearance indicates that bushing replacement is required, all associated components of that connection (the bore into which the bushing is pressed, the pin, the internal diameter of the other bushings through which the pin passes, and/or the tiller arm bores when no bushings are installed therein) must also be inspected and repaired or replaced as necessary. Only by inspection of all related components in the connection can you ensure that the entire cause of any excessive clearance is corrected. When it has been determined that bushing replacement is required, care must be taken to restore the design fit with the bore and the design clearance with the pin. Particularly on older ships, a bushing of design dimensions may not restore either design fit or design clearance due to wear or corrosion of other components. When replacing components, the internal diameter of the bushing and the external diameter of the pin may vary from plan dimensions by no more than 0.010 inch, provided that the clearance between mating parts conforms to plan clearance. All exceptions to this provision require NAVSEA approval. Maintenance is the same as for journal bearings.

561-2.8.13.6 Crosshead Pin Plugs. Crosshead pin plugs are used on each end of crosshead pins to prevent the pins from moving laterally and scoring the guide cylinder liner. Crosshead pin plugs made of DELRIN or UHMWPE should be installed at the outer ends of all guide piston pins when the pistons are removed from their cylinders for any reason. The applicable dimensions for SSBN 616, SSBN 627, SSN 637 (except fairwater crosshead, where a guide cylinder is not used), and SSBN 640 classes are specified in Table 561-2-10. SSN 688 class pins are fastened in place. Since the fasteners would have to fail before the pin could move laterally, plugs are unnecessary. SSBN 726 class has plugs specified in the design drawings. It may be necessary to trim plug ends to ease installation. In some instances, two plug sizes are listed for one pin; this is due to the difference in crosshead pin diameters at the ends of the pin.

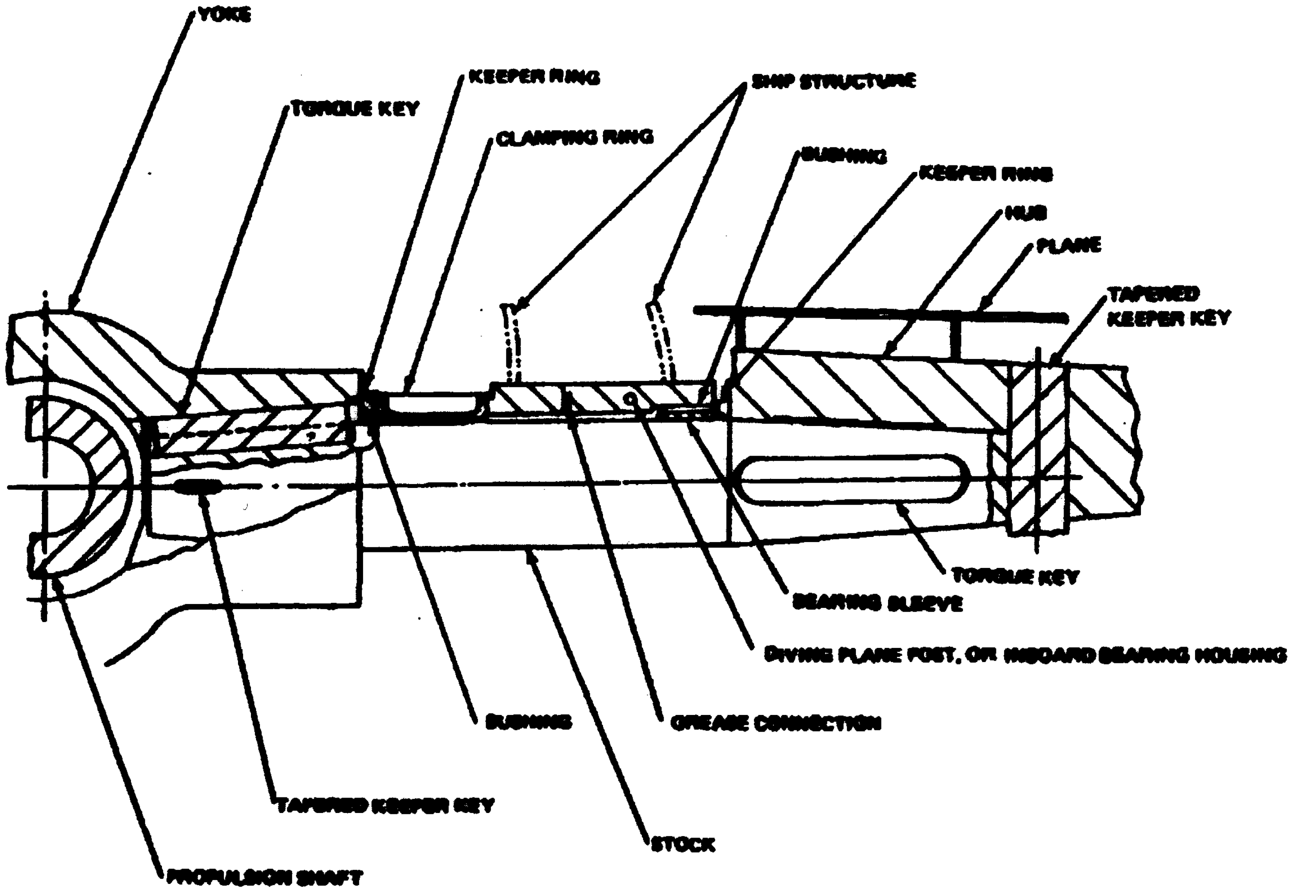


Figure 561-2-25. Stern Diving Plane

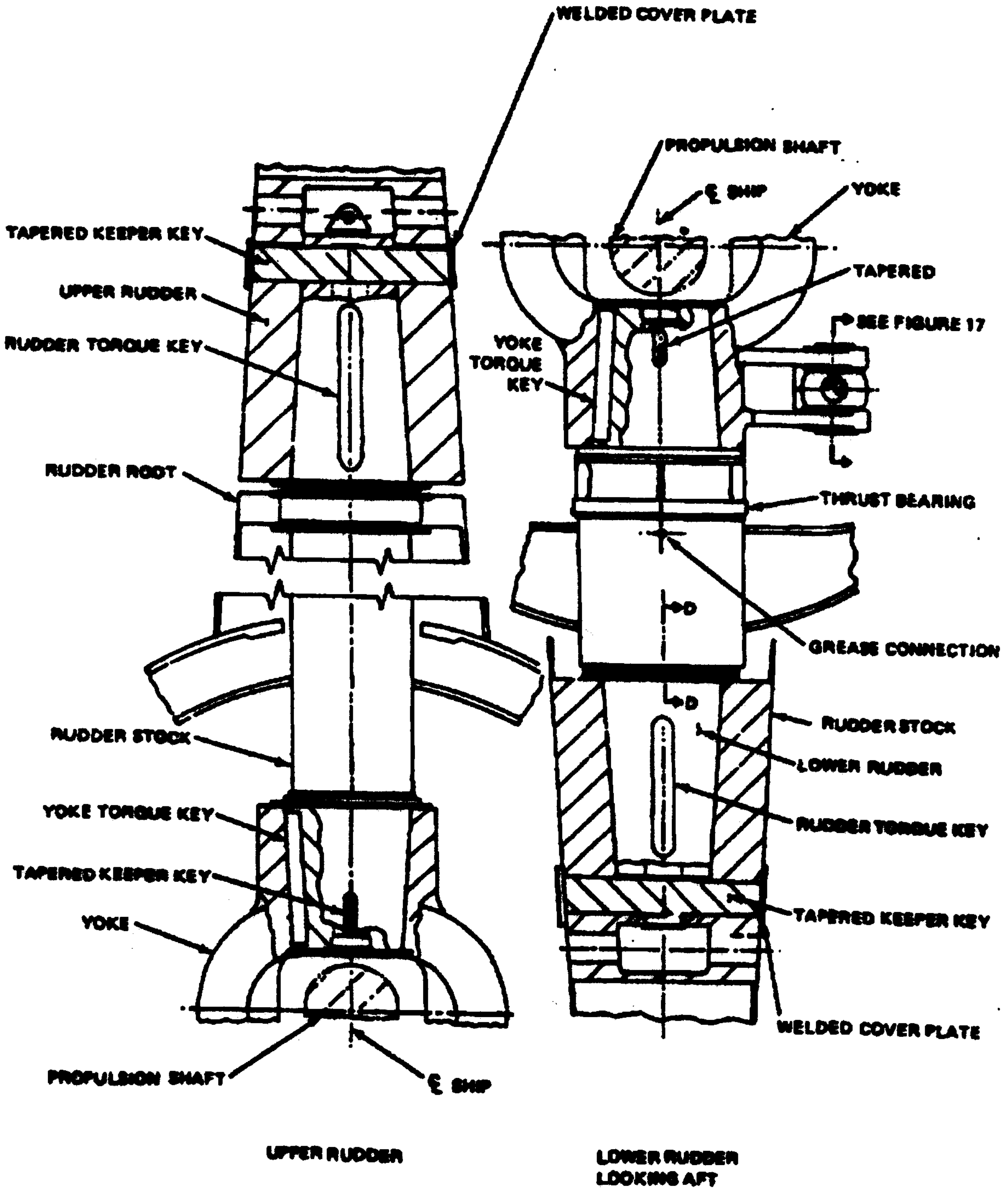


Figure 561-2-26. Rudder Assembly

Table 561-2-10 CROSSHEAD PIN PLUG DIMENSIONS (Unless otherwise shown, tolerance = ±0.005″)

CLASS	DIMENSION	FWTR	STERN	RUDDER
SSBN 616	DIAMETER	3.251″ - 3.254″	5.000″ - 5.002″	5.000″ - 5.002″ 5.254″ NOTE 1.
	THICKNESS	0.225″	0.431″	0.301″
SSBN 627	DIAMETER	3.25″	5.000″ - 5.002″	5.000″ - 5.002″ 5.254″ NOTE 1.
	THICKNESS	0.225″	0.431″	0.301″
SSBN 640	DIAMETER	3.75″	5.000″ - 5.002″	5.000″ - 5.002″ 5.254″ NOTE 1.
	THICKNESS	0.188″	0.431″	0.301″
SSN 637	DIAMETER	N/A	4.252″ - 4.254″	4.252″ - 4.254″ 4.56″ NOTE 1.
	THICKNESS	N/A	0.301″	0.301″

NOTE [1]Two plug sizes are listed for one pin when there is a difference in crosshead pin diameters at the ends of the pin.

561-2.8.13.7 Thrust Washers. Thrust washers are usually made of bronze alloy. These washers are located between the dogbone and tiller arms and between the dogbone and crosshead piston to provide a bearing surface for any side loading that may develop as the control surfaces are moved. (See Figure 561-2-19). Maintenance is the same as for journal bearings, i.e., limited to greasing and periodic measurement as with journal bearings.

561-2.8.13.8 Rudder Carrier Bearings. Rudder carrier bearings transmit the vertical loads imposed by the rudder and its accessories to the hull. There are three potential rotational interfaces for the carrier bearing: between the collar and lower ring; between the lower and upper rings; and between the upper ring and the split spacer. The interface intended for rotational movement is the interface between the upper and lower rings. The lower ring is generally grooved for grease distribution on both its top and bottom surfaces. Inadequate lubrication of the carrier bearing may cause accelerated wear at any of the bearing interfaces. Sufficient wear on either or both of the lower ring's surfaces can completely eliminate the grease grooves. This will make further lubrication impossible and continue to accelerate carrier bearing wear. Rudder thrust clearance measurements and split spacer clearance measurements are intended to indicate the potential decrease in carrier bearing grease groove depth. When either of these clearances indicates that about two thirds of the depth of the grease groove has worn away (usually about 0.020 inch), the rudder should be jacked and blocked in place, the split spacer removed, and all interfaces inspected for wear. If grease grooves are worn to the above limit or other abnormal wear has occurred, repairs should be accomplished immediately.

561-2.8.13.9 Bearing Clearances. Most bearings will require replacement due to noise generation when their clearance approaches or exceeds the value listed in the REPAIR REQUIRED column of Table 561-2-11. The REPAIR REQUIRED column is for use during a ship's operating cycle between scheduled repair availabilities with the intent of providing a margin of wear beyond that amount of wear allowed by TRS, MRC, etc. invoked by scheduled availabilities. As such, Repair Required criteria do not supersede appropriate criteria for scheduled repair availabilities (i.e. TRS for overhauls). When the maximum allowable clearance (REPAIR REQUIRED) for a bearing is reached, repair or replacement is mandatory. Noise generation, drydock availability, operating schedule, overhaul schedule, and common sense will inevitably dictate some variation to these criteria. Criteria provided in Submarine Technical Repair Standards for steering and diving components shall only be used during regular and refueling shipyard overhauls. TRS criteria do not apply during ERPs, SRAs, DMPs, upkeeps and refits, or at any point during the ship's operating cycle. Feeler gauge readings are the preferred method of measuring the clearance of an assembled bearing. Steering and diving planes stock bearings generally exhibit the greatest wear at approximately 200 degrees to 210 degrees and 330 degrees to 340 degrees (with 090 degrees being forward). When possible, clearance measurements using feeler gauges should be taken every 30 degrees. As a minimum, clearance readings should be taken at each end of the 150 degrees - 330 degrees axis (and added together for the diametral clearance) and at each end of the 030 degrees - 210 degrees axis (and also added together). This will provide a view of the worst probable wear locations. On three piece bearings (see paragraph 561-2.8.13.3, above) feeler gauge readings must be taken between the sleeve and the spherical bearing and between the spherical bearing and the bushing. All four measurements on an axis are then added to obtain the total diametral clearance. Although wear may only be taking place on one bearing surface, the total clearance is the distance through which the bearing will move to achieve impact loading. Jacking the bearing while measuring the movement with a dial indicator is an acceptable alternative when the bearing is not easily accessible. Both fore and aft and up and down (left and right for the rudder bearings) jacking measurements should be taken. When repairing or replacing bearing components, always restore design clearances. Adherence to design minimum will extend life of bearing.

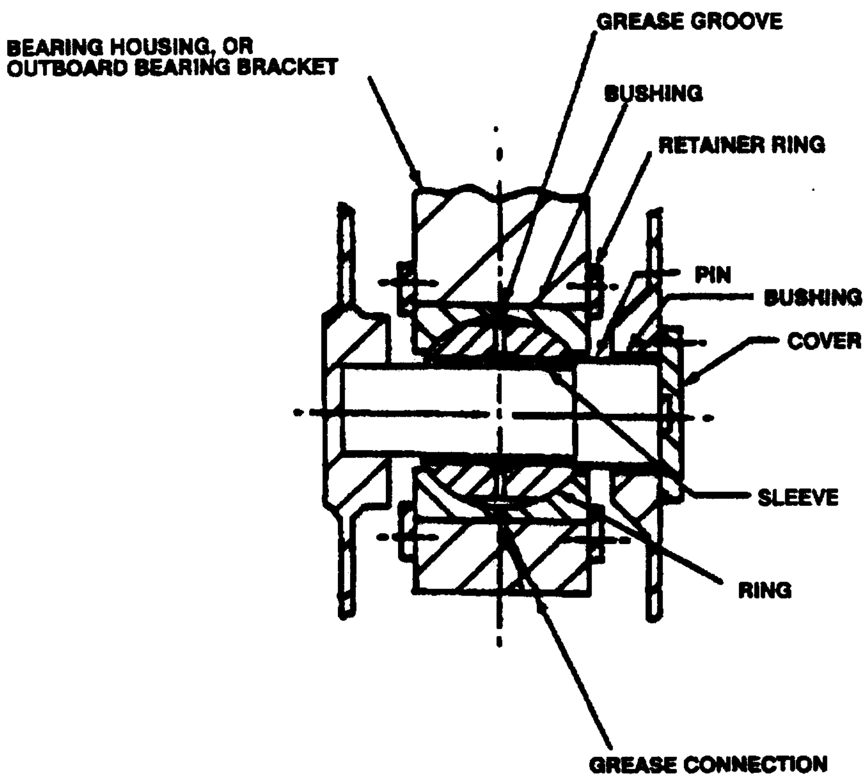


Figure 561-2-27. Typical Outboard Bearing

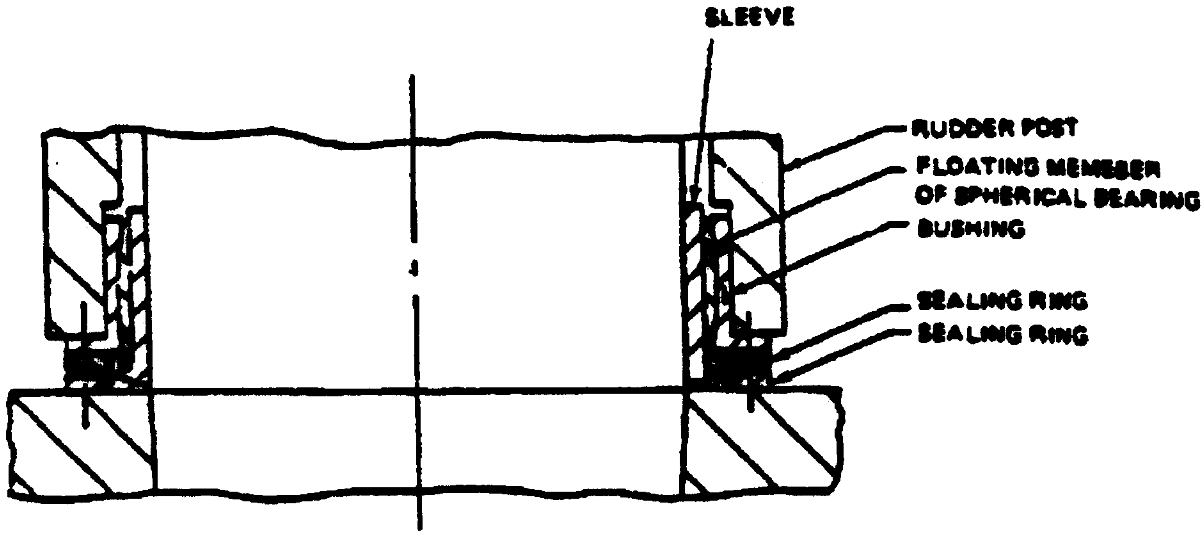


Figure 561-2-28. Typical Rudder Spherical Bearing

561-2.8.13.10 Bearing Clearance Tables. Bearing clearances for several submarine classes for use during the operating cycle are provided in Table 561-2-11 for easy reference. Starred (*) values are minimum clearances; all other values are maximum clearances.

561-2.8.13.11 Stern Planes Pintle Bearing Brackets and Assemblies. NAVSEA S6420-AB-PRO-010, **SSN/SSBN Stern Diving Plane Pintle Bearing Clearance Inspection And Stern Diving Gear Outboard Bearing Bracket Assembly Inspection** , provides detailed inspection and installation guidance for all classes of submarines.

561-2.8.14 FASTENERS. Fasteners for steering and diving equipment should be installed using torques derived from NAVSEA 0900-LP-091-6010, Appendix E. The exceptions to this requirement are those instances when torques are specified for various components in this chapter. When a conflict exists between design drawings and NAVSEA 0900-LP-091-6010, Appendix E, the latter shall take precedence. Subsequent to being torqued, fasteners relax and lose their preload. They must therefore be retorqued, usually two to twenty four hours after initial tightening. Due to this relaxation, LOCKTITE must not be used on bolts and studs under dynamic cyclic loading, since, once the LOCKTITE sets, usually within an hour, the bolt or stud cannot be properly retorqued. The obvious exception to this requirement is at the blind end of a set stud, since the clamping force will be applied using the nut at the open end of the stud.

561-2.8.15 STOCKS. The stocks are forged alloy steel usually with tapers at each end to provide a close fit with both the yoke and plane hub. The tapered ends are machined to provide a metal-to-metal contact of 60 percent minimum for in-service units and 75 percent for units overhauled at a shipyard. Torque keys, usually two, are fitted along the mating surfaces of the stock taper, on the axis of the stock taper. As the name implies these keys transmit or absorb torque that is applied by the hydraulic cylinder to move the control surfaces, by hydrodynamic loading from the sea, or by shock loading. Tapered keeper keys are fitted crosswise through the stocks and into the yoke and plane hubs to pull the tapered stock ends firmly into place. Rather than tapered keeper keys, the SSN 594 Class uses a nut at the outboard end of the stocks to pull the stock into the plane hub.

Table 561-2-11 STEERING AND DIVING BEARING CLEARANCES

SSBN 616 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	1	0.020	0.050
WRIST PIN FREEPLAY	1	0.030	0.050
CONN ROD/TILLER THRUST	2	0.060	0.180
CONN ROD/PISTON THRUST		0.025	0.080
STOCK (INBOARD) BEARING		0.029	0.060
STOCK THRUST		0.060	0.160
PINTLE (OUTBOARD) BEARING		0.010	0.050
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 616 CLASS FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	1	0.014	0.050
WRIST PIN FREEPLAY	1	0.016	0.050
CONN ROD/TILLER THRUST		0.030	0.050
CONN ROD/PISTON THRUST		0.030	0.080
STOCK BEARING		0.034	0.060
STOCK THRUST		0.060	0.160
GUIDE PISTON/CYLINDER LINER		0.023	0.050
SSBN 616 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	1	0.030	0.050
WRIST PIN FREEPLAY	1	0.030	0.050
CONN ROD/TILLER THRUST		0.025	0.080
CONN ROD/PISTON THRUST		0.047	0.080
UPPER STOCK BEARING		0.033	0.075
LOWER STOCK BEARING		0.033	0.075
STOCK THRUST		0.145	0.165
CARRIER SPLIT SPACER		0.047*	0.011*
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 627 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	1	0.030	0.050
WRIST PIN FREEPLAY	1	0.030	0.050
CONN ROD/TILLER THRUST	2	0.060	0.160
CONN ROD/PISTON THRUST		0.025	0.080
STOCK (INBOARD) BEARING		0.029	0.060
STOCK THRUST		0.060	0.160
PINTLE (OUTBOARD) BEARING		0.010	0.050
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 627 CLASS FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	1	0.014	0.050
WRIST PIN FREEPLAY	1	0.016	0.050
CONN ROD/TILLER THRUST		0.030	0.080
CONN ROD/PISTON THRUST		0.030	0.080
STOCK BEARING		0.034	0.060
STOCK THRUST		0.060	0.160
GUIDE PISTON/CYLINDER LINER		0.023	0.050

Table 561-2-11 STEERING AND DIVING BEARING CLEARANCES - Continued

SSBN 627 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.030	0.050
WRIST PIN FREEPLAY	[1]	0.030	0.050
CONN ROD/TILLER THRUST		0.025	0.080
CONN ROD/PISTON THRUST		0.046	0.080
UPPER STOCK BEARING		0.033	0.075
LOWER STOCK BEARING		0.033	0.075
STOCK THRUST		0.145	0.165
CARRIER SPLIT SPACER		0.047*	0.011*
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 640 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.030	0.060
WRIST PIN FREEPLAY	[1]	0.030	0.050
CONN ROD/TILLER THRUST	[2]	0.060	0.160
CONN ROD/PISTON THRUST		0.020	0.080
STOCK (INBOARD) BEARING		0.018	0.060
STOCK THRUST		0.060	0.160
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 640 CLASS FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.016	0.050
WRIST PIN FREEPLAY	[1]	0.016	0.050
CONN ROD/TILLER THRUST		0.031	0.080
CONN ROD/PISTON THRUST		0.031	0.080
STOCK BEARING		0.020	0.060
STOCK THRUST		0.060	0.160
GUIDE PISTON/CYLINDER LINER		0.023	0.050
SSBN 640 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.029	0.050
WRIST PIN FREEPLAY	[1]	0.030	0.050
CONN ROD/TILLER THRUST		0.020	0.080
CONN ROD/PISTON THRUST		0.020	0.080
UPPER STOCK BEARING		0.022	0.080
LOWER STOCK BEARING		0.033	0.075
STOCK THRUST		0.188	0.208
CARRIER SPLIT SPACER		0.047*	0.011*
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 726 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.043	0.055
WRIST PIN FREEPLAY	[1]	0.045	0.055
CONN ROD/TILLER THRUST		0.100	0.160
CONN ROD/PISTON THRUST		0.090	0.160
STOCK (INBOARD) BEARING		0.010	0.065

Table 561-2-11 STEERING AND DIVING BEARING CLEARANCES - Continued

STOCK THRUST		0.100	0.160
PINTLE (OUTBOARD) BEARING		0.021	0.060
GUIDE PISTON/CYLINDER LINER		0.035	0.070
SSBN 726 CLASS FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.030	0.050
WRIST PIN FREEPLAY	[1]	0.025	0.060
CONN ROD/TILLER THRUST		0.200	0.230
CONN ROD/PISTON THRUST		0.065	0.100
STOCK BEARING		0.055	0.080
STOCK THRUST		0.150	0.200
PINTLE (OUTBOARD) BEARING		0.021	0.050
GUIDE PISTON/CYLINDER LINER		0.030	0.065
SSBN 627 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.053	0.065
WRIST PIN FREEPLAY	[1]	0.043	0.055
CONN ROD/TILLER THRUST		0.090	0.120
CONN ROD/PISTON THRUST		0.090	0.120
UPPER STOCK BEARING		0.020	0.080
LOWER STOCK BEARING		0.020	0.080
STOCK THRUST		0.055	0.105
CARRIER SPLIT SPACER	[3]	N/A	N/A
GUIDE PISTON/CYLINDER LINER		0.035	0.070
SSBN 637 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.033	0.045
WRIST PIN FREEPLAY	[1]	0.033	0.045
CONN ROD/TILLER THRUST	[2]	0.060	0.120
CONN ROD/PISTON THRUST		0.020	0.090
STOCK (INBOARD) BEARING		0.018	0.060
STOCK THRUST		0.060	0.120
PINTLE (OUTBOARD) BEARING		0.021	0.050
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 637 CLASS FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.014	0.050
WRIST PIN FREEPLAY	[1]	0.014	0.050
CONN ROD/TILLER THRUST	[2]	0.030	0.100
CONN ROD/PISTON THRUST		0.030	0.080
STOCK BEARING		0.018	0.065
STOCK THRUST		0.060	0.120
GUIDE SLIDE/CROSSHEAD		0.026	0.050
SSBN 637 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.033	0.045
WRIST PIN FREEPLAY	[1]	0.022	0.045

Table 561-2-11 STEERING AND DIVING BEARING CLEARANCES - Continued

CONN ROD/TILLER THRUST		0.020	0.080
CONN ROD/PISTON THRUST		0.020	0.080
UPPER STOCK BEARING		0.032	0.075
LOWER STOCK BEARING		0.032	0.075
STOCK THRUST		0.188	0.208
CARRIER SPLIT SPACER		0.047*	0.011*
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 671 STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.033	0.045
WRIST PIN FREEPLAY	[1]	0.022	0.045
CONN ROD/TILLER THRUST	[2]	0.060	0.120
CONN ROD/PISTON THRUST		0.020	0.090
STOCK (INBOARD) BEARING		0.010	0.060
STOCK THRUST		0.060	0.120
PINTLE (OUTBOARD) BEARING		0.021	0.050
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 671 FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.020	0.050
WRIST PIN FREEPLAY	[1]	0.016	0.050
CONN ROD/TILLER THRUST		0.030	0.100
CONN ROD/PISTON THRUST		0.030	0.080
STOCK BEARING		0.029	0.065
STOCK THRUST		0.060	0.120
GUIDE SLIDE/CROSSHEAD		0.030	0.050
SSBN 671 RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.031	0.045
WRIST PIN FREEPLAY	[1]	0.022	0.045
CONN ROD/TILLER THRUST		0.020	0.080
CONN ROD/PISTON THRUST		0.020	0.080
UPPER STOCK BEARING		0.022	0.075
LOWER STOCK BEARING		0.022	0.075
STOCK THRUST		0.188	0.208
CARRIER SPLIT SPACER		0.047*	0.011*
GUIDE PISTON/CYLINDER LINER		0.022	0.050
SSBN 688 CLASS STERN PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.012	0.040
WRIST PIN FREEPLAY	[1]	0.012	0.040
CONN ROD/TILLER THRUST		0.070	0.160
CONN ROD/PISTON THRUST		0.102	0.140
STOCK (INBOARD) BEARING		0.018	0.065
STOCK THRUST		0.060	0.160
PINTLE (OUTBOARD) BEARING		0.014	0.050
GUIDE PISTON/CYLINDER LINER		0.026	0.050

Table 561-2-11 STEERING AND DIVING BEARING CLEARANCES - Continued

SSBN 688 FAIRWATER PLANES			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.019	0.050
WRIST PIN FREEPLAY	[1]	0.017	0.050
CONN ROD/TILLER THRUST		0.103	0.140
CONN ROD/PISTON THRUST		0.103	0.140
STOCK (BEARING)		0.032	0.070
STOCK THRUST W/O S/A 3604	[4]	0.060	0.120
STOCK THRUST WITH S/A 3604	[4]	0.100	0.150
GUIDE PISTON/CYLINDER LINER		0.025	0.050
SSBN 688 CLASS RUDDER			
BEARING		**DESIGN MAX**	**REPAIR REQUIRED**
TILLER PIN FREEPLAY	[1]	0.018	0.040
WRIST PIN FREEPLAY	[1]	0.018	0.040
CONN ROD/TILLER THRUST		0.140	0.180
CONN ROD/PISTON THRUST		0.102	0.140
UPPER STOCK BEARING		0.034	0.075
LOWER STOCK BEARING		0.034	0.075
STOCK THRUST		0.188	0.208
CARRIER SPLIT SPACER		0.188*	0.146*
GUIDE PISTON/CYLINDER LINER		0.023	0.050

[1]This value has a double meaning. When an assembled freeplay (double clearance) is measured, the value is the maximum allowable freeplay for the connection. When the connection is disassembled and the bearing components are measured by micrometer, this value is both the maximum allowable freeplay for the connection and the maximum allowable individual clearance between the wrist or tiller pin and any mating bore.

[2]In order to prevent excessive wear or bending of the connecting rod caused by athwartship movement of the yoke, this clearance must be restored to the value indicated instead of the per plan design clearance.

*Starred (*) values are minimum clearances; all other values are maximum clearances.

[3]Clearance is established at final assembly between split spacer and lower rudder post, and stamped on aft side of lower rudder post. Allowed reduction from this initial measurement is 0.020.

[4]Readings taken forward and aft between keeper ring and bushing flange.

561-2.9 MOLECULAR METAL COATING FOR RESURFACING OF COMPONENTS

561-2.9.1 APPLICABLE COMPONENTS. The use of Belzona Molecular Super Metal Coating (Belzona Molecular Inc., Garden City, NY) is authorized for repair of corroded or damaged components in static and non-load bearing areas of the following steering gear, stern diving gear, and fairwater diving gear components:

a. Fairwater diving gear hydraulic ram head static O-ring or quad-ring grooves.

b. Cross head-to-tiller connecting rod including rod end thrust faces where damage does not exceed 1/4 inch depth on nonbearing surfaces or 3/64 inch on thrust faces.

c. Guide cylinder outside diameter where damage does not exceed 1/8 inch depth.

d. Guide cylinder hull fitting external and internal surfaces, excluding sealing surface for guide cylinder cover o-rings or sealing sleeve o-rings, where damage does not exceed 1/8 inch depth.

e. Yoke internal and external surfaces where damage does not exceed 1/4 inch depth. Coating shall not be used in key slots, in areas where covers or pads are to be welded, on tiller arms to depths greater than 3/64 inch, or in taper bores where coating constitutes greater than 1 percent continuous coverage.

f. Control surface stocks where damage does not exceed 3/16 inch depth. Do not use coating on stock tapers where coating constitutes greater than 1 percent continuous coverage, or in key slots.

g. Control surface hub internal and external surfaces where damage does not exceed 1/4 inch depth. Do not use coating in areas where covers or pads are to be welded, in taper bores where coating constitutes greater than 1 percent continuous coverage, in key slots except for fairwater diving gear axial keys.

h. Control surface stock seal rings, thrust rings, and split spacers.

561-2.9.1.1 Application. Depths stated in paragraph 561-2.9.1 include clean-up and excavation required in preparation of surface for coating application. Coating shall be considered to have no strength value with respect to the structural integrity of the components on which it is applied. Before surface preparation required by the coating manufacturer, bake all components previously subjected to oil or grease at 375°F for a minimum of eight hours to remove petroleum residue.

561-2.9.1.2 Restrictions and Reporting. Although use of Molecular Metal repair is encouraged for those applications stated in paragraph 561-2.9, specific NAVSEA approval is required before use in all other areas. Document and report use to NAVSEA so that inspection of repairs may be made during subsequent availabilities to determine in-service durability and acceptability. Report documents shall include ship number, date of application, drawing number and part number of component on which repair was used, and a description of the area and extent of repair.

561-2.9.1.3 Control Surfaces. Control surfaces are usually fabricated of hull-type steel plating placed over a structural framework. Control surfaces, which are watertight, are internally supported against sea pressure by either plastic (syntactic-foam) filler or end-grained wood and vegetable pitch. Control surfaces should be checked periodically for leakage. If the control surface is to be removed, leakage can then be detected by weighing the control surface and comparing the current weight to the as-manufactured weight. If leakage is to be checked with the plane in place a small inspection hole may have to be cut in the plane. Filler material should be inspected and maintained in accordance with the appropriate TRSs.

561-2.9.1.3.1 Because parts of the steering and diving gear are located in freeflood areas, they are almost continually submerged in seawater even when the submarine is on the surface (only the fairwater diving gear is not submerged when the submarine is surfaced).

561-2.9.1.3.2 The stabilizer and stern plane surface plates should be visually inspected for dents, cracks, and pits. Dents up to 3/4 inches below the molded line are permitted aft of the 10 percent chord line, measured from the leading edge. Dents forward of the 10 percent chord line should not exceed 1/2 inch in depth below the molded line. Not more than 2 percent of the total surface area forward of the 10 percent chord line and not more than 10 percent of the total surface area aft of the 10 percent chord line is allowed to be dented, subject to the above criteria. Pitting of the control surface should be inspected and repaired in accordance with **NSTM Chapter 074 Volume 1, Welding and Allied Processes** , and the appropriate Technical Repair Standards. Rudders and planes should be operated to check performance, ease of movement, and the absence of any unusual noise. This check should be conducted at dockside.

SECTION 3.

OPERATING LIMITATIONS

561-3.1 CONTROL SURFACE RATES

561-3.1.1 For most classes of submarines, the original shipbuilding specifications identify the range of acceptable control surface rates. For most later classes of submarines, the rate ranges are from 5 to 9 degrees per second for the diving planes and from 3 to 5 degrees per second for the rudder. In many cases, the hydraulic power plant supplying power to the control surfaces is not designed to provide simultaneous operation of the control surfaces at the maximum rate. Therefore, if the control surface rates are set at the maximum allowable limit, the chances of saturating the power plant increase; that is, it becomes more probable that emptying the accumulators will result in temporary reduction or loss of hydraulic system pressure.

561-3.2 CONTROL SURFACE RATE SELECTION

561-3.2.1 On some classes of submarines, the design rates selected by the design activity are identified on steering and diving system drawings. When the rates are not specifically identified on system diagrams, the following documentation should be used for guidance in selecting the rate to support the Unrestricted-Operations (URO) program:

a. URO-MRC 019 (paragraph 561-4.3) for bow diving and stern diving systems.

b. Original shipbuilding specifications. The control surface rate should be set at the midpoint of the allowable range during dockside system grooming. A slightly reduced rate will exist during at-sea operation as a result of additional hydrodynamic loading of the control surfaces. Therefore, the rate should be checked during normal at-sea operation and verified to be above the minimum allowable. On a few systems it may not be possible to obtain the specified rates at maximum ship speed, because of marginal designs.

561-3.3 ASTERN SPEED LIMITATIONS FOR SURFACE OPERATION OF THE RUDDER

561-3.3.1 Submarine steering systems are sized for ahead operation, and their limitations on surfaced operation astern are deliberately accepted. Full astern propeller speed is allowed for stopping or slowing the ship. However, once the ship starts moving astern, the steering gear provides rudder control only for low astern speeds. Control at higher speeds would usually require a much larger hydraulic cylinder and often an increased output capacity of the hydraulic power plant. The allowable sustained surface speed astern is accordingly defined as the number of propeller revolutions per minute (r/min) that can be allowed continuously if the rudder orders are still to be followed. This number of r/min is determined from actual sea trials with hydraulic cylinder pressures observed while astern propeller speed is systematically increased. Once defined, the maximum allowable sustained surface speed astern is permanently identified on a warning plate installed aboard ship. This sustained speed must not be exceeded for the following reasons:

a. Adequate ship control cannot be maintained with smaller rudder angles.

b. Larger rudder angles will result in overpressurization of the operating cylinder and piping, with possible damage to the system. On ships with relief valves installed, the relief valves will lift and the rudder will be driven into the hardstops. Because it will be impossible to move the rudder off the hardstop position until astern speed is reduced, loss of control will occur.

SECTION 4.

OVERALL MATERIAL AND MAINTENANCE REQUIREMENTS

561-4.1 STEERING AND DIVING HYDRAULIC SYSTEM MATERIAL IDENTIFICATION AND CONTROL (LEVEL I)

561-4.1.1 Portions of the steering and diving hydraulic systems require Level I material identification in accordance with NAVSEA 0948-LP-045-7010, **Material Identification and Control (MIC) for Piping Systems** . In general, hydraulic systems, including components such as valves and piping, for any steering or diving control surface, failure of which would cause loss of both the normal and emergency modes of control surface operation, are designated Level I. Refer to applicable ships drawings for identification of Level I components and required material.

561-4.2 STEERING AND DIVING MATERIAL CERTIFICATION REQUIREMENTS FOR THE SUBMARINE SAFETY PROGRAM

561-4.2.1 NAVSEA 0924-LP-062-0010, **Submarine Material Certification Requirements Manual, for the Submarine Safety Program** specifies the minimum actions required to provide a satisfactory level of confidence in both the integrity of submarine systems and the adequacy of certain damage control capabilities. The following elements of the diving system are considered to be within the submarine material certification boundary:

a. Bow diving gear linkage from the hydraulic cylinder up to and including the bow diving planes.

b. Hydraulic piping and components that are necessary for both the normal and emergency operational modes of both the bow and stern diving system (fairwater diving is excepted), including any normally shut isolation valves that form a boundary for that portion of the system that is common to both normal and emergency modes.

c. The diving control sticks and their stern diving gear linkage from the hydraulic cylinder up to and including the stern diving planes. Associated linkages up to but not including any hydraulic control valve operated by the control stick and linkage.

d. All bow and stern diving control and feedback linkages and all linkage associated with normal, auxiliary, or mechanical indication of bow or stern plane angles.

561-4.2.2 Material certification is jeopardized every time work is done, for any reason, within the established submarine material certification boundary. This includes work done: during the operating period; during an overhaul or availability period; for incorporation of alterations, modifications, or changes; for corrective maintenance; or as part of the preventive maintenance program.

561-4.2.3 To ensure that steering and diving system material conditions remain satisfactory to support continued certification, the requirements of NAVSEA 0924-LP-062-0010 shall be complied with whenever work involving SUBSAFE elements of the diving system is performed.

561-4.3 STEERING AND DIVING SYSTEM URO-MRCs

561-4.3.1 NAVSEA 0924-LP-062-0010 specifies the maintenance requirements and identifies the responsibilities and actions necessary to support continued unrestricted submarine operations to design test depth.

1. The maintenance requirements under this
2. Unrestricted-Operations (URO) program are issued in Maintenance Requirement Cards (MRCs) format. The intent of the URO-MRCs is to ensure early identification of any degradation of the material condition within the hull integrity boundary and those systems affecting ship recoverability.
3. The URO-MRCs concerning steering and diving are as follows:
   a. MRC-015-Inspect Bow and Stern Diving Gear.
   b. MRC-016-Inspect Internal Control Linkage in Bow and Stern Diving Gear.
   c. MRC-019-Conduct Operational Test of Bow and Stern Diving Systems.
   d. MRC-020-Inspect Internal Surfaces of 2014/2017 Series Aluminum Alloy Component Bodies Installed in the Bow and Stern Diving Hydraulic System.
   e. MRC-021-Inspect Surfaces of 2024 Series Aluminum Alloy Component Bodies Installed in the Bow and Stern Diving Hydraulic System.

APPENDIX A.

STEERING AND DIVING HYDRAULIC CYLINDER INTERNAL REPAIR

561-A.1 METHOD 1

561-A.1.1 Defects in bores of hydraulic cylinders, which are chrome plated, may be repaired by honing out (overboring) the defects and restoring the inside diameters of the hydraulic cylinder to drawing dimensions by either CRES sleeving or chrome plating. As required by Section 9210-1-c of the **General Overhaul Specification for Deep Diving SSBN/SSN Submarines** (NAVSEA 0902-LP-018-2010), chrome plating is used to restore defects up to 0.010 in. deep and CRES sleeving, an expensive and difficult process, is used to restore defects deeper than 0.010 inch. See Table 561-A-1 and Figure 561-A-1 for sleeving details.

561-A.2 METHOD 2

561-A.2.1 Defects in bores of hydraulic cylinders may be repaired by overboring the hydraulic cylinder inside diameter a maximum of 0.040 in. beyond the drawing diameter (on SSN688 and SSBN726 classes overboring is only allowed on the inside diameter in way of the piston travel). See Appendix B, hydraulic cylinder head repair for oversized cylinders, to maintain drawing clearances and seal compression. The increase in piston and head diameters (for SSN688 and SSBN726 classes only the piston requires a corresponding increase to maintain drawing clearance), must not be accomplished by chrome plating.

561-A.2.2 In addition, the final inside diameter and plating thickness of overbored cylinders must be documented for the next overhauling activity on the ship's Selected Record Drawing (SRD) titled, ″Steering and Diving Hydraulic System Tables″. A label plate shall be affixed to the overbored cylinder indicating the dimensions of the final inside diameter and plating thickness.

NOTE

Method 2 is more economical than Method 1 and is the preferred repair.

Table 561-A-1 DIMENSIONS FOR STEERING AND DIVING HYDRAULIC CYLINDER INTERNAL SLEEVING CLASS CYLINDER DIMENSION A REFERENCE

CLASS	CYLINDER	DIMENSION A	REFERENCE
637	FWTR	12″ + 1/64″	518-2143705
637	STERN	9-1/2″ + 1/64″	518-2143678
637	RUDDER	11″ + 1/64″	518-2143669
671	FWTR	9″ + 1/64″	518-2047379
671	STERN	10″ + 1/64″	518-2047352
671	RUDDER	11-1/2″ + 1/64″	518-2047343
616	FWTR	11″ + 1/64″	518-2005261
616	STERN	10-1/2″ + 1/64″	518-2005242
616	RUDDER	13-1/8″ + 1/64″	518-2005233
640	FWTR	11-1/2″ + 1/64″	518-2118745 518-2150531

Table 561-A-1 DIMENSIONS FOR STEERING AND DIVING

HYDRAULIC CYLINDER INTERNAL SLEEVING CLASS CYLINDER

DIMENSION A REFERENCE - Continued

CLASS	CYLINDER	DIMENSION A	REFERENCE
640	STERN	11-1/2″ + 1/64″	518-2118725 518-2149812
640	RUDDER	13-1/2″ + 1/64″	518-2118717 518-2149813

Sleeve, PC 1, as identified in Figure 561-A-1, to CRES H.R. ANL QQ-S-766 CL 316L 5/8″ plate. Use referenced drawings for dimensions and details not specifically mentioned in Figure 561-A-1.

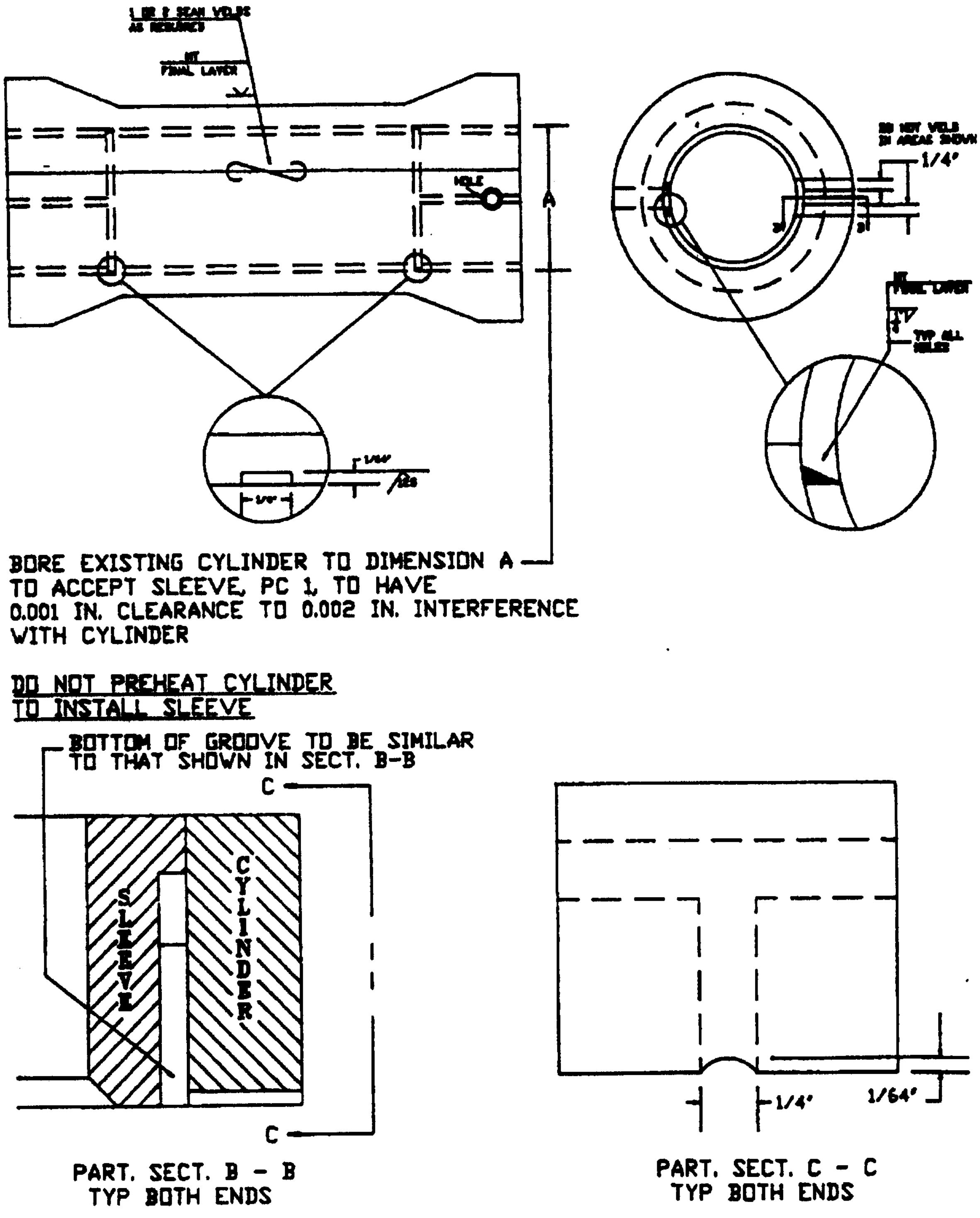


Figure 561-A-1 Steering and Diving Hydraulic Cylinder Internal Sleeving

APPENDIX B.

STEERING AND DIVING HYDRAULIC CYLINDER HEAD SLEEVING PROCEDURE

561-B.1

In lieu of manufacturing a new cylinder head to meet acceptance criteria if the hydraulic cylinder is overbored to restore the finish, the following repair procedure may be used. The procedure requires that the existing cylinder head is machined and a new sleeve is manufactured so that it can be threaded onto the cylinder heads to maintain drawing clearances and seal compression. The sleeve material is to be NI-AL-BRZ, QQ-C-465B alloy C63200. Use Figure 561-B-1, Table 561-B-1 and referenced drawings for details and dimensions. This procedure is only approved for those cylinders which are listed in Table 561-B-1″.

General Notes

1. The following figures were developed to provide instruction for sleeving undersized hydraulic cylinder heads when overboring of the hydraulic cylinder is accomplished by Appendix A.
2. Final dimensions should be machined after installation of the sleeve to the head except for mating surfaces which must be finish machined prior to assembly.
3. Threads between cylinder head and sleeve must be sealed with anaerobic compound per MIL-S-22473, (LOCKTITE GR271) or equivalent as follows: With 1″ to 1-3/8″ of sleeve internal thread protruding, apply anaerobic compound to remaining internal threads before completing installation.
4. Machine sleeve flush with cylinder head within 0.001″ after assembly.
5. Provide a 3/16″ wide undercut to root diameter. Radius corners to 0.010″.
6. Final dimensions to provide 0.002″ to 0.006″ diametral clearance with hydraulic cylinder.
7. Threads to be 12UN-3B for sleeve and 12UN-3A for cylinder head.
8. Mating sealing surface between sleeve and cylinder head must be Rhr 32 or smoother on both sleeve and cylinder head.
9. Just prior to installing sleeve on cylinder head, to prevent pinching the o-ring, apply clean 2190 TEP oil to o-ring, o-ring groove and mating sealing surface on cylinder head.
10. Tighten sleeve on cylinder head to provide a metal-to-metal contact fit with cylinder head.
11. The applicable cylinder head drawing, referenced in Table 561-B-1, must be used to provide dimensions not specifically given in the figures.
12. The hydraulic cylinder head must satisfactorily pass a hydrostatic/tightness test.
13. Sleeving of hydraulic cylinder heads must be documented on the ships selected record drawing (SRD) titled, ″Steering and Diving Hydraulic System Tables″.
14. Tolerances must be as follows, unless indicated in Figure 561-B-1:

    Fractions: ± 1/64″

    Decimals: ± 0.010″

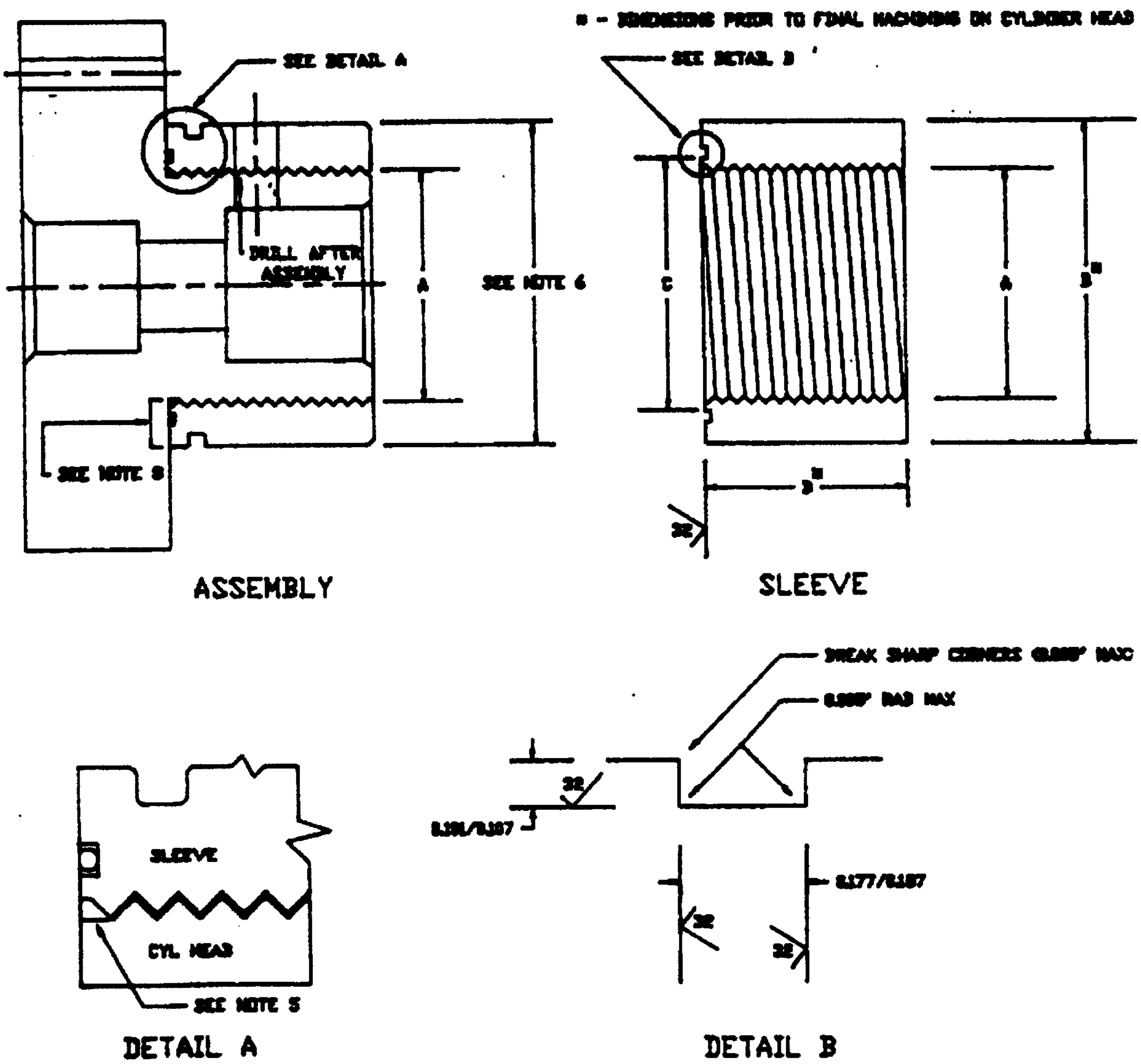


Figure 561-B-1. Typical Hydraulic Cylinder Head Sleeving

Table 561-B-1 DIMENSIONS FOR HYDRAULIC CYLINDER HEAD SLEEVING

STEERING HYDRAULIC CYLINDER HEAD					
CLASS	**DIM A**	**DIM B**	**DIM C**	**DIM D**	**REFERENCE**
637	9.000″	10-5/8″	9.500″	4-1/4″ 4-3/4″	518-2143669
671	9.500″	11-1/8″	10.000″	4-11/16″	518-2047343
616	11.000″	12-3/4″	11.500″	4-3/8″	518-2005233
640	11.500″	13-1/8″	12.000″	4-1/2″	518-2118717
STERN DIVING HYDRAULIC CYLINDER HEAD					
637	7.500″	9-1/8″	8.000″	4-1/2″	518-2143678
671	8.000″	9-5/8″	8.500″	4-5/8″	518-2047352

Table 561-B-1 DIMENSIONS FOR HYDRAULIC CYLINDER HEAD

SLEEVING - Continued

STEERING HYDRAULIC CYLINDER HEAD					
CLASS	**DIM A**	**DIM B**	**DIM C**	**DIM D**	**REFERENCE**
616	8.500″	10-1/8″	9.000″	4-3/16″	518-2005241
640	9.500″	11-1/8″	10.000″	4-1/4″	518-2118725
FAIRWATER DIVING HYDRAULIC CYLINDER HEAD					
637*	10.000″	11-5/8″	10.500″	4-1/4″	518-2143705
671	7.000″	8-5/8″	7.500″	5-3/8″	518-2047379
616	9.000″	10-5/8″	7.500″	5-3/8″	518-2005261
640	9.000″	11-1/8″	9.500″	5-1/4″	518-2118745

*Lower hydraulic cylinder head only. Not recommended for upper cylinder head.

APPENDIX C.

STEERING AND DIVING HYDRAULIC CYLINDER HEAD BUSHING FOR SSN 688 CLASS SUBMARINES

561-C.1

The following repair procedure may be used to restore the hydraulic cylinder head to design operating clearances with the operating rod or piston rod. Machine the existing head and manufacture a bushing that can be placed in the cylinder using Figure 561-C-1 and Table 561-C-1 for details and dimensions. This repair procedure is not applicable to forward cylinder heads on the steering gear, the forward cylinder heads on SSN 718 stern diving or the lower heads on the fairwater diving cylinder heads.

General Notes

1. Threads between bushing and cylinder head shall be set with anaerobic compound Grade AV or AVV per MIL-S-22473 (LOCKTITE GR271) or equivalent.
2. After final machining, drill and tap 1/4-20UNC-3B X 3/8 deep 2 places 180 degrees apart, for hex socket set screw, on Dimension ″2″. Set with anaerobic compound used in Note 1. Stake in place. All surfaces to be flush or recessed.
3. Machine this face flush with cylinder head mating surface within 0.001″.
4. Machine approximately 1/32″ longer than recess it is to be screwed into.
5. Bushing material to be NI-AL-BRZ, QQ-C-465B alloy C63200 or equivalent.
6. Set screw material to be NI-CU, QQ-N-281, 1/4-20UNC-3A X 3/8 long.
7. Use referenced drawings for details and dimensions not specifically mentioned in figures.
8. Tolerances shall be as follows:

   Fractions: ± 1/64″

   Angles: ± 0 degrees 30 minutes

   Decimals: As Shown

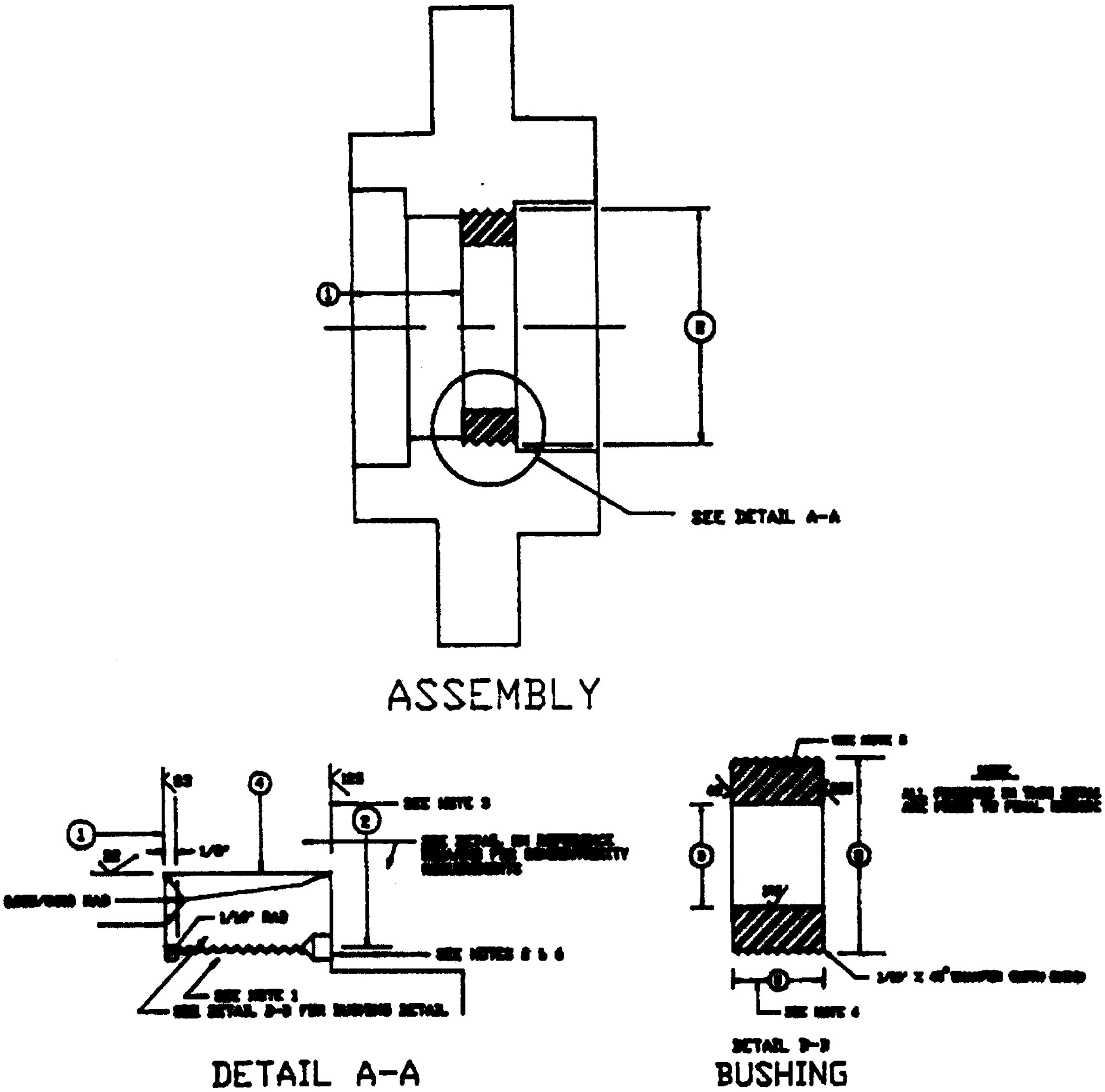


Figure 561-C-1 Typical 688 Class Hydraulic Cylinder Head Bushing

Table 561-C-1 DIMENSIONS FOR 688 CLASS HYDRAULIC CYLINDER HEAD BUSHING

STEERING GEAR AFT CYLINDER HEAD					
DIM 1	DIM 2 *	DIM 3	DIM 4	DIM 5	REFERENCE
3.644″/3.746″ ***	6″	4-15/16″	5.001 ± 0.001	1-15/16″/1-7/8″ ***	518-4457086
STERN DIVING GEAR FORWARD AFT CYLINDER HEAD					
3.644″/4.121″ ***	6″	4-7/16″	4.501 ± 0.001	1-13/16″/1-3/8″**	518-4457083
STERN DIVING GEAR AFT CYLINDER HEAD (SSN718)					
3.531″	4″	3-3/16″	3.251 ± 0.001	1-3/8″	518-5529816

Table 561-C-1 DIMENSIONS FOR 688 CLASS HYDRAULIC CYLINDER HEAD BUSHING - Continued

STEERING GEAR AFT CYLINDER HEAD					
DIM 1	**DIM 2 ***	**DIM 3**	**DIM 4**	**DIM 5**	**REFERENCE**
FAIRWATER DIVING GEAR UPPER CYLINDER HEAD					
4.306″/4.492″ **	6″	3-15/16″	4.000 ± 0.001	1-1/2/1-1/16″ ***	518-4457128

DIM 1- Reference Dimensions

DIM 2- Thread Diameter

*- Threads to be 12UN-2A on bushing and 12UN-2B on cylinder head.

DIM 3- Nominal inside diameter of unfinished bushing

DIM 4- Final inside diameter of bushing

DIM 5- Nominal width of unfinished bushing

***- Applicable to reference drawing, revision v and later.

**- Applicable to reference drawing, revision p and later.

APPENDIX D.

STEERING AND DIVING HYDRAULIC CYLINDER HEAD BUSHING FOR PRE SSN 688 CLASS SUBMARINES

561-D.1

The following repair procedure may be used to restore the hydraulic cylinder head to design operating clearances with the operating rod or piston rod. Machine the existing head and manufacture a bushing that can be placed in the cylinder head using Figure 561-D-1 and Table 561-D-1 for details and dimensions. This repair procedure is not applicable to forward/lower cylinder heads unless otherwise indicated in Table 561-D-1.

General Notes

1. Threads to be 12UN-3A on Bushing and 12UN-3B in cylinder head.
2. Threads between bushing and cylinder head shall be set with anaerobic compound Grade AV or AVV per MIL-S-22473 (LOCKTITE GR271) or equivalent.
3. After final machining, drill and tap 1/4-20UNC-3B X 3/8 deep 2 places 180 degrees apart, for hex socket set screw, on Dimension ″A″. Set with anaerobic compound used in Note 2. Stake in place. All surfaces to be flush or recessed.
4. Set screw material to be NI-CU, QQ-N-281, 1/4-20UNC-3A X 3/8 long.
5. Machine bushing cavity in the cylinder head to a depth that is flush with the bottom of the existing packing cavity (Dimension C). Surface finish to be per referenced drawing.
6. Bushing material to be NI-AL-BRZ, QQ-C-465B alloy C63200 or equivalent.
7. Machine this face flush with cylinder head mating surface within 0.001″.
8. Use referenced drawings for details and dimensions not specifically mentioned in figures.
9. Tolerances shall be as follows:

   Fractions: ± 1/64″

   Angles: ± 0 degrees

   30 minutes

   Decimals: As Shown

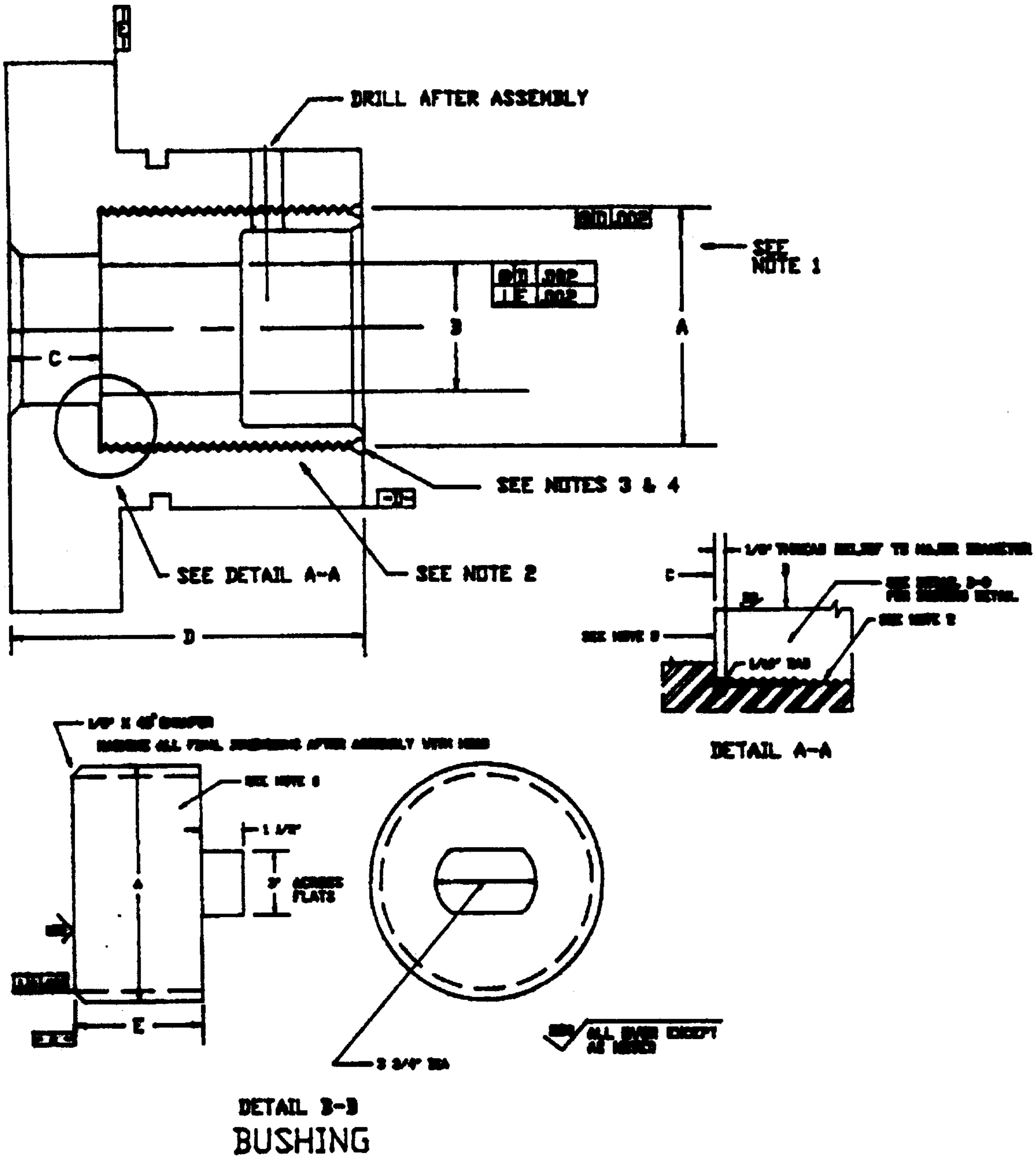


Figure 561-D-1 Typical Pre 688 Class Hydraulic Cylinder Head Bushing

Table 561-D-1 DIMENSIONS FOR PRE 688 CLASS HYDRAULIC CYLINDER HEAD BUSHING

STEERING GEAR						
CLASS	**DIM A**	**DIM B**	**DIM C**	**DIM D**	**DIM E**	**REFERENCE**
637	USE MOD DRAWING SSN 637-518-5308285					
671	7″	4.501 ± 0.001	2.250 ± 0.010	7-1/16″	4-7/8″	518-2047343
616*	7-3/4″	4.501 ± 0.001	2.140 ± 0.010	7-5/16″	5-1/4″	518-2005233
640	8″	5.001 ± 0.001	2.1225 ± 0.0025	7-3/8″	5-5/16″	518-2118717
641	8″	5.001 ± 0.001	2.1225 ± 0.0025	8-1/8″	6-1/16″	518-2149813
STERN DIVING GEAR						
CLASS	DIM A	DIM B	DIM C	DIM D	DIM E	REFERENCE
637	USE MOD DRAWING SSN 637-518-5308285					
671	6″	4.001 ± 0.001	2.250 ± 0.010	7-1/4″	5-1/16″	518-2047352
616*	6-1/2″	3.501 ± 0.001	1.875 ± 0.010	6-9/16″	4-3/4″	518-2005241
640	7″	4.501 ± 0.001	2.1225 ± 0.0025	6-7/8″	4-7/8″	518-2118725
FAIRWATER DIVING GEAR						
671**	6-1/2″	4.001 ± 0.001	2.130 ± 0.005	7-1/2″	5-7/16″	518-2047379
616*	7″	4.251 ± 0.001	2.140 ± 0.010	7-3/4″	5-11/16″	518-2005261
640	7″	4.501 ± 0.001	2.1225 ± 0.0025	7-7/8″	6-13/16″	518-2118745

*- Dimension for 12UN-3 threads

APPENDIX E.

STEERING AND DIVING HYDRAULIC CYLINDER FITTED BOLT BUSHING

561-E.1

The following methods may be used to repair hydraulic cylinder rams in the way of the fitted bolt holes.

Method 1: Weld repair the hydraulic rams and re-machine the bores to provide original drawing tolerances with the fitted bolts. This procedure may cause warpage and should be done with caution.

Method 2: Using Figure 561-E-1 and Table 561-E-1 as guides, overbore the fitted bolt holes and manufacture bushings to be installed in the hydraulic ram bolt holes. Machine bushings to provide original drawing tolerance with fitted bolts.

General Notes

1. Manufacture bushings from HY-80 barstock, MIL-S-21952.
2. Tack weld each bushing in place on the spotface side of the mounting using a minimum of 1/4″ long 1/8″ groove welds on each bushing.
3. Touch-up spotfaces, removing the minimum amount of material necessary to smooth off tack welds and restore squareness of spotfaces to the pre-drilled bushing bores.
4. Size bushing OD to provide 0.000″ to 0.002″ interference fit with the prepared bolt holes.
5. Machine as built diametral clearance just prior to installing fitted bolts to ensure of achieving plan fit.

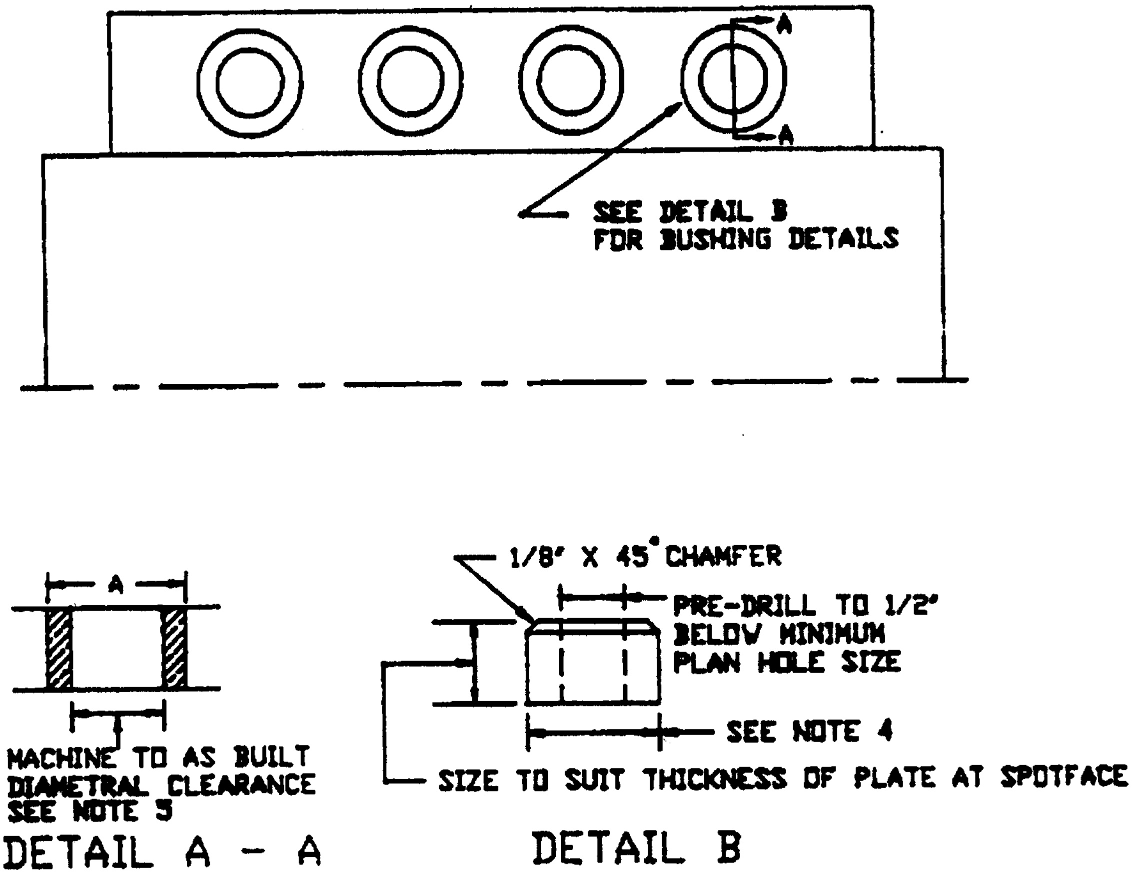


Figure 561-E-1 Steering and Diving Hydraulic Cylinder Fitted Bolt Bushing

Table 561-E-1 DIMENSIONS FOR STEERING AND DIVING HYDRAULIC CYLINDER FITTED BOLT BUSHINGS

STEERING GEAR		
CLASS	**PLAN DIMENSION**	**DIMENSION A**
637	1.531″	2″
	1.031″	1-5/16″
671	1.375″	1-3/4″
688	1.500″	1-3/4″
	1.125″	1-5/16″
616	1.500″	2″
640	1.781″	2-1/8″
	1.156″	1-1/2″
	1-7/8″*	2-1/8″
	1-1/2″*	2″
	1.906″**	2-3/8″
	1.281″**	1-3/4″
STERN DIVING GEAR		
637	1.406″	1-13/16″
	1.031″	1-5/16″
671	0.875″	1-1/4″

Table 561-E-1 DIMENSIONS FOR STEERING AND DIVING

HYDRAULIC CYLINDER FITTED BOLT BUSHINGS - Continued

STEERING GEAR		
CLASS	**PLAN DIMENSION**	**DIMENSION A**
688	1.500″	1-3/4″
	1.250″#	1-1/2″
616	1.375″	1-3/4″
640	1.531″	2″
	1.031″	1-5/16″
	1-1/2″##	2″
FAIRWATER DIVING GEAR		
637	1.531″	2″
671	1.375″	1-3/4″
688	N/A	N/A
616	1-13/32″	1-11/16″
640	1.531″	2″
	1-7/16″ +	1-13/16″

*- Applicable to SSBN's 641 & 644.

**- Applicable to SSBN 654 through SSBN 659.

#- Applicable to SSN 718

##- Applicable to SSBN's 641 & 644

+- Applicable to SSBN 641

APPENDIX F.

STEERING AND DIVING GUIDE CYLINDER COVER BUSHING

561-F.1

The following repair procedure may be used to restore the guide cylinder cover to design operating clearances with the operating rod. Machine the existing cover and manufacture a bushing that can be placed in the cover using Figure 561-F-1 and Table 561-F-1 for details and dimensions.

General Notes

1. Thread fit of ″A″ on Bushing and bore ″B″ in cylinder head.

2. Threads between bushing and guide cylinder cover shall be set with anaerobic compound Grade AV or AVV per MIL-S-22473 (LOCKTITE GR271) or equivalent.

3. After final machining, drill and tap 1/4-20UNC-3B X 3/8 deep 2 places 180 degrees apart, for hex socket set screw, on Dimension ″A″. Set with anaerobic compound used in Note 2. Stake in place. All surfaces to be flush or recessed.

4. Set screw material to be NI-CU, QQ-N-281, 1/4-20UNC-3A X 3/8 long.

5. Machine this face flush with guide cylinder cover mating surface within 0.001″.

6. Bushing material to be NI-AL-BRZ, QQ-C-465B alloy C63200 or equivalent.

7. Surface finish to be per referenced drawing.

8. Use referenced drawings for details and dimensions not specifically mentioned in the figures.

9. Tolerances shall be as follows:

   Fractions: ± 1/64

   Angles: ± 0 degrees

   30 minutes

   Decimals: As Shown

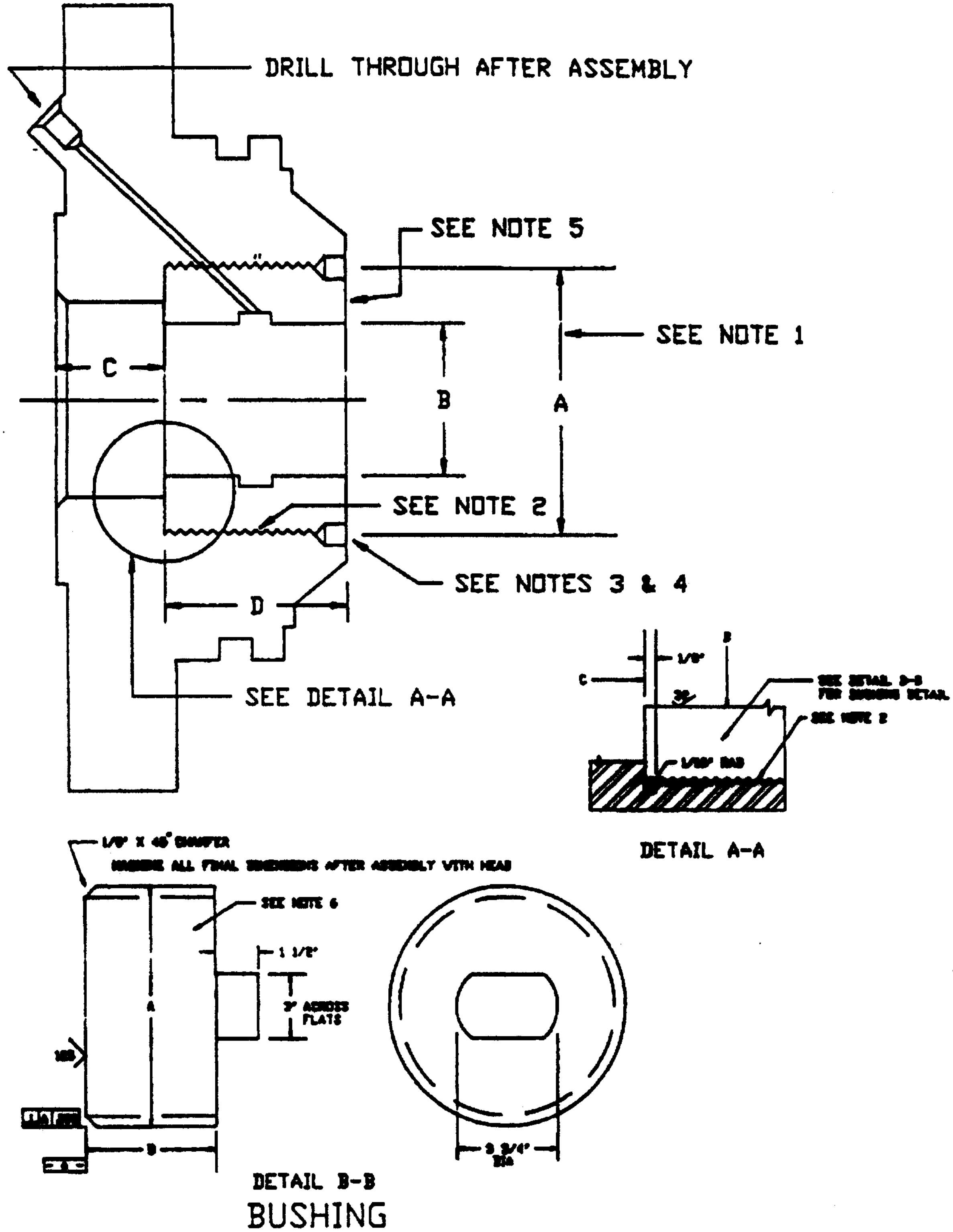


Figure 561-F-1 Guide Cylinder Cover Bushing

Table 561-F-1 DIMENSIONS FOR STEERING AND DIVING GUIDE CYLINDER COVER BUSHING

STEERING GEAR					
CLASS	**DIM A** *	**DIM B**	**DIM C**	**DIM D**	**REFERENCE**
637	USE DRAWING 518-5157643 AS REFERENCE GUIDE				
616	6-1/2″	4.510 ± 0.001	1.890 ± 0.001	4-3/8″	518-2005236
640	6-1/2″	5.010 ± 0.001	1.8725 ± 0.0005	3-1/8″	518-2118720
STERN DIVING GEAR					
637	USE DRAWING 518-5157643 AS REFERENCE GUIDE				
616	5-1/4″	4.013 ± 0.001	1.890 ± 0.001	3-3/8″	518-2005244
640	6-1/2″	4.513 ± 0.001	1.8725 ± 0.0005	3-1/8″	518-2118728
FAIRWATER DIVING GEAR					
616	5-1/2″	4.2565 ± 0.0005	1.890 ± 0.001	3-3/8″	518-2005260
640	6-1/2″	4.5075 ± 0.0015	1.873 ± 0.002	2-5/8″	518-2118744

*- Dimension for 12UN-3 threads.

APPENDIX G.

STEERING AND DIVING GUIDE CYLINDER PISTON BUSHING

561-G.1

The following repair procedure may be used to restore the clearances between the guide cylinder piston and the guide cylinder pin. Machine the existing guide cylinder piston and manufacture new bushings which would be installed into the guide cylinder piston. Bushing material to be NI-AL-BRZ, QQ-C-465B alloy C63200 or equivalent. Use Figure 561-G-1, Table 561-G-1, and referenced drawings for details and dimensions.

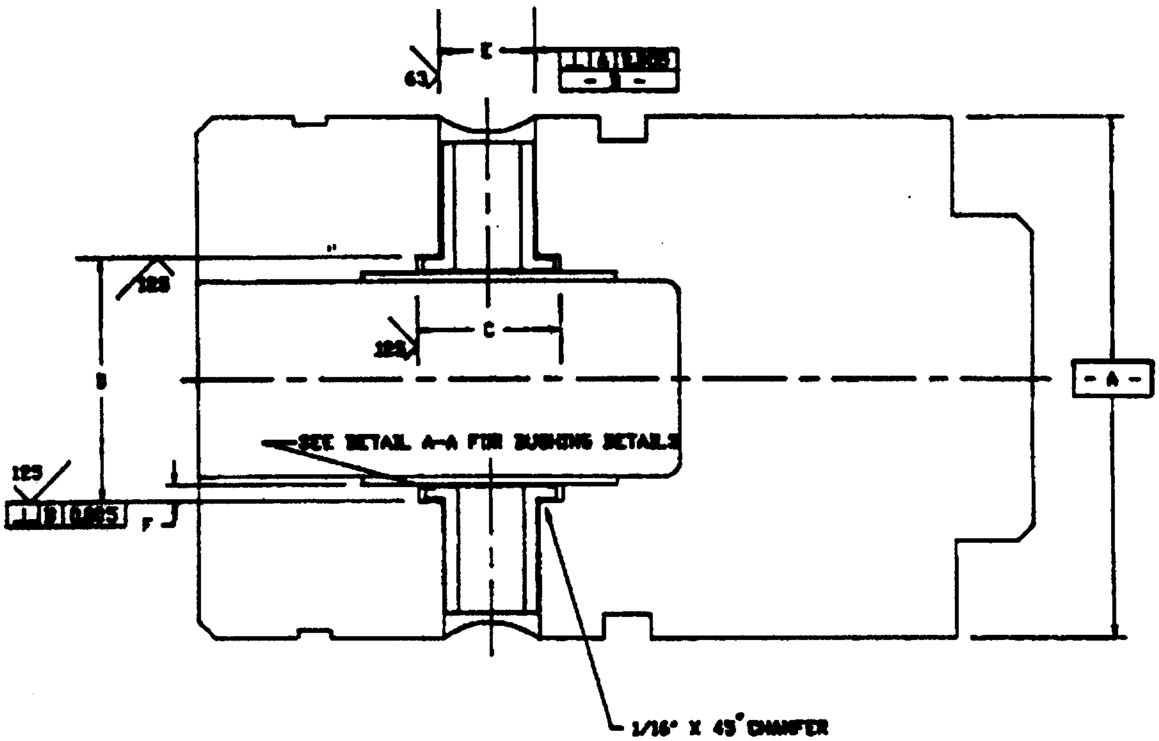
Tolerances shall be as follows:

Fractions: ± 1/64

Angles: ± 0 degrees

30 minutes

Decimals: As Shown



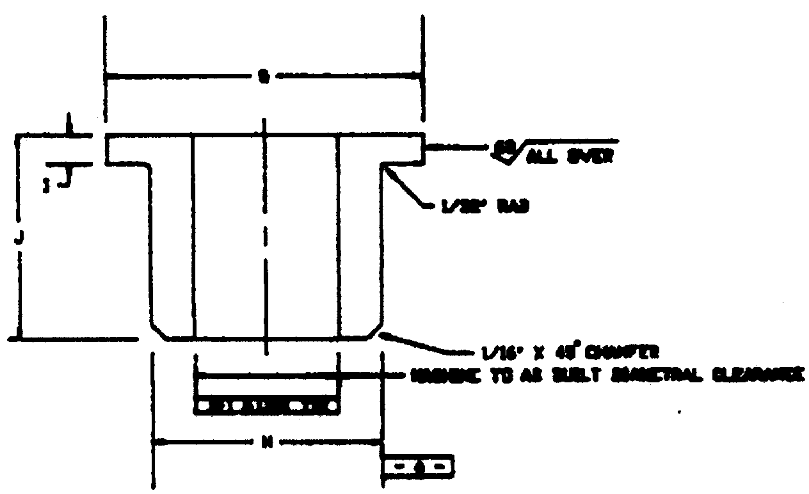


Figure 561-G-1 Guide Cylinder Piston Bushing

Table 561-G-1 DIMENSIONS FOR GUIDE CYLINDER PISTON BUSHING STEERING GEAR

CL	DIM C	DIM D	DIM E	DIM F	DIM G	DIM H	DIM I	DIM J	REFERENCE
637	5-7/8″	6-3/4″	5.003 ± 0.001	3/8″	5-3/4″	5.002 ± 0.001	11/32″	2-1/8″	518-2143671
671	6-3/8″	6-3/4″	5.503 ± 0.001	3/8″	6-1/4″	5.502 ± 0.001	11/32″	3″	518-2047345
688	6-3/8″	6-5/16″	5.502 ± 0.001	3/8″	6-1/4″	5.5025 ± 0.0005	11/32″	2-9/16″	518-4457076
616	6-5/8″	7-3/4″	5.751 ± 0.001	3/8″	6-1/2″	5.7515 ± 0.0005	11/32″	3-1/4″	518-2005235
640	6-3/8″	8-1/4″	5.751 ± 0.001	3/8″	6-1/4″	5.7515 ± 0.0005	11/32″	2-15/16″	518-2118719
STERN DIVING GEAR									
637	5-7/8″	6-3/4″	5.003 ± 0.001	3/8″	5-3/4″	5.0035 ± 0.0005	11/32″	2-1/2″	518-2143680
671	5-7/8″	6-3/4″	5.003 ± 0.001	3/8″	5-3/4″	5.0035 ± 0.0005	11/32″	2-1/2″	518-2047354
688 *	5-5/8″	6-5/16″	4.752 ± 0.001	3/8″	5-1/2″	4.7525 ± 0.0005	11/32″	2-9/16″	518-4457080
718 **	3-1/2″	4-1/2″	3.252 ± 0.001	3/8″	3-3/4″	3.2525 ± 0.0005	11/32″	2-11/16″	518-5529809
616	6-3/8″	6″	5.751 ± 0.001	3/8″	6-1/4″	5.7515 ± 0.0005	11/32″	2-7/16″	518-2005243
640	6-3/8″	6-3/4″	5.7505 ± 0.0005	3/8″	6-1/4″	5.7515 ± 0.0005	5/16″	2-1/8″	518-2118727
FAIRWATER DIVING GEAR									
637	4-7/8″	5-3/8″	4.0025 ± 0.0015	3/8″	4-3/4″	4.0035 ± 0.0005	11/32″	1-5/8″	518-2047378
671	6-5/8″	6-9/16″	5.753 ± 0.001	3/8″	6-1/2″	5.7535 ± 0.0005	11/32″	2-9/32″	518-4457126
616	4-3/8″	5-1/16″	5.751 ± 0.001	1/4″	4-1/4″	3.7515 ± 0.0005	7/32″	1-1/4″	518-2005259
640	6″	6-5/16″	4.5005 ± 0.0005	3/8″	5-5/8″	4.5015 ± 0.0005	13/32″	1-15/16″	518-2118743

*- Applicable to SSN 718 No. 2 Guide Piston.

**- Applicable to SSN 718 No. 1 Guide Piston ONLY.

APPENDIX H.

STEERING AND DIVING TILLER ARM BUSHING

561-H.1

The following repair procedure may be used to restore the plan clearances between the tiller arm and tiller pin. This procedure allows the overboring of the tiller arms to allow a bushing to be installed to restore the pin clearance. For those classes of submarines that do not have bushings installed during new construction, do not have new construction drawings that could be utilized or do not have ShipAlts that would accomplish the bushing, use Figure 561-H-1 and Table 561-H-1 for details and dimensions for adding bushings to the tiller arms. OD's of the bushings in Table 561-H-1 may not be increased. Bushing material to be QQ-C-465B alloy C63200 or equivalent.

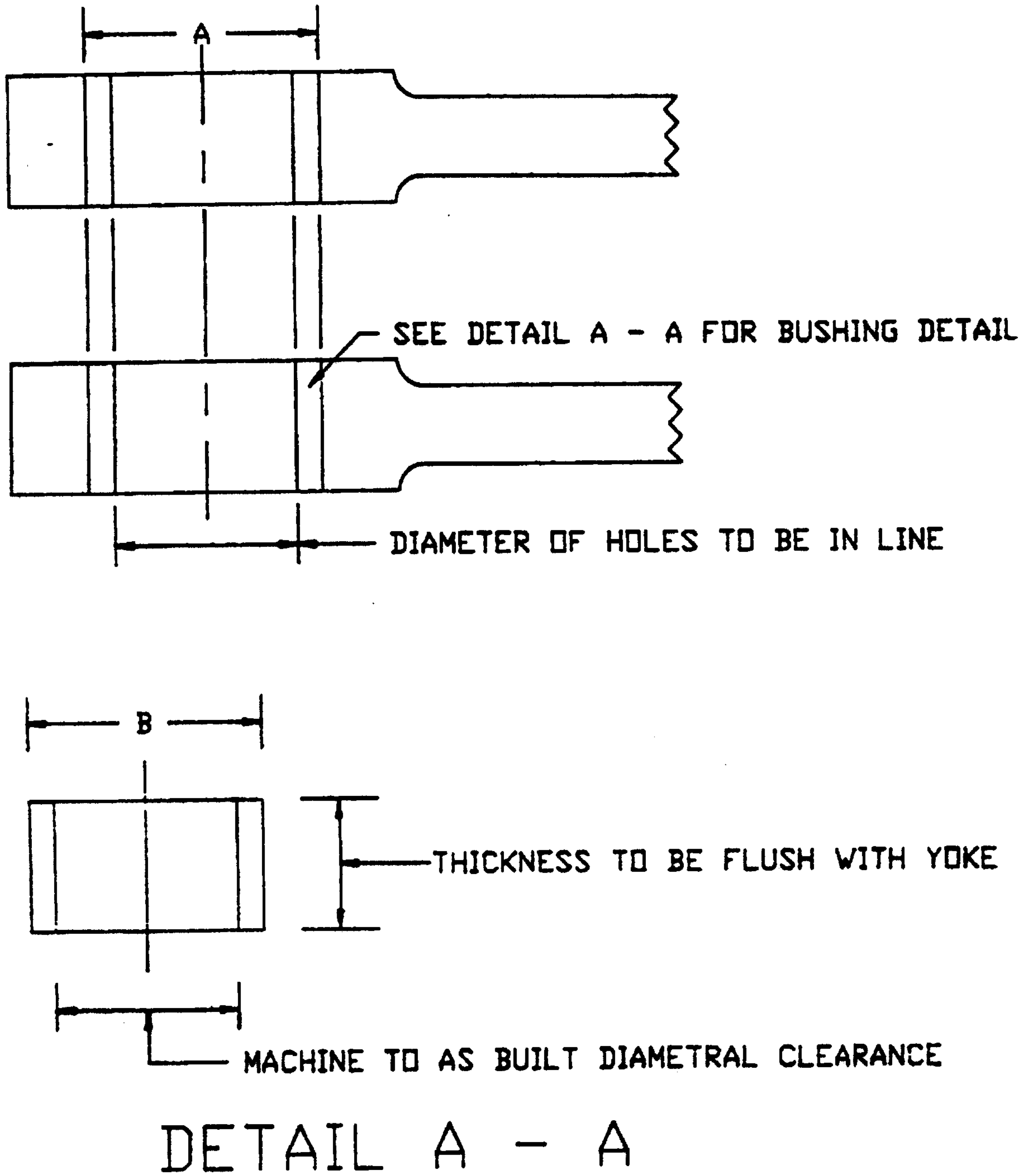


Figure 561-H-1 Steering and Diving Tiller Arm Bushing

Table 561-H-1 DIMENSIONS FOR STEERING AND DIVING TILLER ARM BUSHING STERN GEAR

SHIP CLASS	DIM A	DIM B	REFERENCE
616	5.500/5.501	5.501/5.502	518-2007121
640	5.750/5.751	5.751/5.752	518-2452193 518-2116832 518-2437193

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.